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Influence of Frequent Nightmares on REM Sleep-Dependent Emotional Memory Processing

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Résumé

La littérature suggère que le sommeil paradoxal joue un rôle dans l'intégration associative de la mémoire émotionnelle. De plus, les rêves en sommeil paradoxal, en particulier leur nature bizarre et émotionnelle, semblent refléter cette fonction associative et émotionnelle du sommeil paradoxal. La conséquence des cauchemars fréquents sur ce processus est inconnue, bien que le réveil provoqué par un cauchemar semble interférer avec les fonctions du sommeil paradoxal.

Le premier objectif de cette thèse était de reproduire conceptuellement des recherches antérieures démontrant que le sommeil paradoxal permet un accès hyper-associatif à la mémoire. L'utilisation d'une sieste diurne nous a permis d'évaluer les effets du sommeil paradoxal, comparativement au sommeil lent et à l'éveil, sur la performance des participants à une tâche sémantique mesurant « associational breadth » (AB). Les résultats ont montré que seuls les sujets réveillés en sommeil paradoxal ont répondu avec des associations atypiques, ce qui suggère que le sommeil paradoxal est spécifique dans sa capacité à intégrer les traces de la mémoire émotionnelle (article 1). En outre, les rapports de rêve en sommeil paradoxal étaient plus bizarres que ceux en sommeil lent, et plus intenses émotionnellement ; ces attributs semblent refléter la nature associative et émotionnelle du sommeil paradoxal (article 2).

Le deuxième objectif de la thèse était de préciser si et comment le traitement de la mémoire émotionnelle en sommeil paradoxal est altéré dans le Trouble de cauchemars fréquents (NM). En utilisant le même protocole, nos résultats ont montré que les participants NM avaient des résultats plus élevés avant une sieste, ce qui correspond aux observations antérieures voulant que les personnes souffrant de cauchemars soient plus créatives. Après le sommeil paradoxal, les deux groupes, NM et CTL, ont montré des changements similaires dans leur accès associatif, avec des résultats AB-négatif plus bas et AB-positif plus grands. Une semaine plus tard, seul les participants NM a maintenu ce changement dans leur réseau sémantique (article 3). Ces résultats suggèrent qu'au fil du temps, les cauchemars peuvent interférer avec l'intégration de la mémoire émotionnelle pendant le sommeil paradoxal. En ce qui concerne l'imagerie, les participants NM avaient plus de bizarrerie et plus d'émotion positive, mais pas négative, dans leurs rêveries

(article 4). Ces attributs intensifiés suggèrent à nouveau que les participants NM sont plus imaginatifs et créatifs à l'éveil.

Dans l'ensemble, les résultats confirment le rôle du sommeil paradoxal dans l'intégration associative de la mémoire émotionnelle. Cependant, nos résultats concernant le Trouble de cauchemars ne sont pas entièrement en accord avec les théories suggérant que les cauchemars sont dysfonctionnels. Le groupe NM a montré plus d'associativité émotionnelle, de même que plus d'imagerie positive et bizarre à l'éveil. Nous proposons donc une nouvelle théorie de *sensibilité environnementale* associée au Trouble de cauchemar, suggérant qu'une sensibilité accrue à une gamme de contextes environnementaux sous-tendrait les symptômes uniques et la richesse imaginative observés chez les personnes souffrant de cauchemars fréquents. Bien que davantage de recherches doivent être faites, il est possible que ces personnes puissent bénéficier e milieux favorables, et qu'elles puissent avoir un avantage adaptatif à l'égard de l'expression créative, ce qui est particulièrement pertinent lorsque l'on considère leur pronostic et les différents types de traitements.

Mots-clés : cauchemars, sommeil paradoxal, rêves, rêveries, mémoire émotionnelle, mémoire associative

Abstract

Existing literature suggests that REM sleep plays a role in the associative integration of emotional memory, and that attributes of dreams during REM sleep, particularly their bizarre and emotional nature, either reflect or even influence this associative and emotional function. The consequence of frequent nightmares on this process is unknown, although, the experience of a nightmare suggests an associative restriction imposed by intense negative emotion, consistent with research showing that negative affect tends to restrict cognitive flexibility in wake. This is consistent with existing theories of nightmare function, largely purporting that nightmares reflect temporary failures in emotion regulation.

The first objective of the thesis was to conceptually replicate prior research portraying REM sleep as enabling increased associative access to emotional memory. The use of a daytime nap allowed us to assess the effects of REM sleep, compared to both NREM sleep and waking, on participant performance on a novel task measuring Associational Breadth (AB). Results showed that only those subjects awakened from REM sleep responded with atypical emotional word associations, suggesting that REM is specific in its capacity to broadly integrate emotional memory traces (article 1). Further, REM dream reports were more bizarre than both NREM dreams and waking daydreams, and more emotionally intense than NREM dreams; these attributes are thought to reflect the hyper-associative and emotional nature of REM sleep (article 2).

The second objective was to clarify whether and how REM sleep-dependent emotional memory processing is altered in frequent nightmares sufferers. Using a similar nap protocol, our results showed that NM participants had higher baseline AB in response to emotional cue-words, contrary to predictions, but nonetheless corresponding with anecdotal reports of heightened creativity. Following REM sleep, both NM and CTL groups showed similar changes in associative access to emotional cue-words, with negative AB being restricted and positive AB being broadened; one week later, the NM group alone maintained this altered pattern of emotional semantic access (article 3). This finding suggests that, over time, nightmares may interfere with REM sleep-dependent emotional memory integration. Regarding imagery, the NM participants had heightened bizarreness, and positive, but not negative, imagery in their

daydreams, but not their dreams (article 4), mirroring our AB finding that the NM group had significantly higher emotional associativity in wake, although patterns of associativity following a REM sleep nap did not differ between groups.

Overall, findings support a role of REM sleep in the associative integration of emotional memory. However, our findings regarding nightmare sufferers are not entirely consistent with views that nightmares are associated with dysfunctional emotional memory processing. Although they did show a prolonged priming effect suggestive of inadequate emotion regulation, they also showed heightened semantic associativity and vivid positive imagery in wake. We therefore propose a novel Environmental Sensitivity framework for the study of nightmare sufferers, claiming that an increased sensitivity to a range of environmental contexts, not only negative contexts, underlies the unique symptoms and imaginative richness seen in frequent nightmare sufferers. Although further empirical research exploring potentially adaptive traits or sensitivity to positive contexts in nightmare sufferers is needed, the possibility that these individuals may benefit especially from supportive environments, and may have heightened creativity and semantic associativity, is particularly relevant when considering prognosis and treatment approaches.

Keywords: nightmares, REM sleep, dreams, daydreams, emotional memory, associative memory

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List of abbreviations

AB: Associational Breadth

ANOVA: Analysis of Variance

BD/wk: Bad Dreams per week

BDI: Beck Depression Index

CTL: Control group

D/wk: Dreams per week

DSM-5: The Diagnostic and Statistical Manual of Mental Disorders

M: Mean

NM: Nightmare

ns: Not significant

NREM: Non-rapid eye movement

PE: Priming effect

REM: Rapid eye movement

RT: Reaction Time

SD: Standard deviation

SE: Standard error

STAI : Spielberger State and Trait Anxiety Inventory

TAS: Toronto Alexithymia Scale

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1. Introduction

A growing body of evidence suggests that sleep is not only involved in, but also sometimes critical for, the consolidation of learning and memory, and this function includes roles for both NREM and REM sleep. Several studies have shown NREM sleep to be associated with improvements in episodic memory, which refers to the consolidation of specific memories for personal experiences (Plihal & Born, 1997). REM sleep, on the other hand, may function to integrate these personal experiences into broad memory networks, establishing associations between recent and remote experiences (Gujar, McDonald, Nishida, & Walker, 2011; Rauchs, Desgranges, Foret, & Eustache, 2005; Stickgold, 2005; Walker & Stickgold, 2006). In this manner, NREM and REM sleep may work together to consolidate and integrate recent events into broad memory networks, allowing us to learn from experiences and better prepare for similar situations in the future.

Many experimental studies assessing the consolidation patterns of NREM compared with REM sleep have used semantic tasks to measure the relative breadth of spreading activation in semantic memory networks in either state. Spreading activation refers to a process by which the activation of one item in a semantic memory network spreads to surrounding items by virtue of their associative closeness (Anderson, 1983). Specifically, during REM sleep, as opposed to during either NREM sleep or wake, there may be a broader spread of activation through semantic networks enabling more distant, uncommon or atypical semantic associations to be activated (Stickgold, Scott, Rittenhouse, & Hobson, 1999). This broad spreading activation could allow recent memories for specific experiences to be integrated within a vast network of related experiences from the more distant past. Several recent findings support such a general associative function of REM sleep. For instance, participants awakened from REM sleep and immediately administered an associative task display quicker access to distantly related words (e.g., bread-health) whereas participants awakened from NREM sleep, or tested during wake, display quick access only for closely related words (e.g., bread-butter; Stickgold et al., 1999). These findings are thought to reflect the generally heightened associativity and spread of activation during REM sleep, as compared to NREM sleep or wake.

In addition to evidence that associative spread in memory networks changes across sleep stages, a growing literature suggests that REM sleep is essential for the specific consolidation of emotional stimuli (Gujar et al., 2011; Lara-Carrasco, Nielsen, Solomonova, Levrier, & Popova, 2009; Nishida, Pearsall, Buckner, & Walker, 2009; van der Helm et al., 2011; Wagner, Gais, & Born, 2001). For instance, studies have found REM sleep to be necessary for the consolidation of fear and safety memories, or for remembering the negative components of complex pictures (Marshall et al., 2014; Payne et al., 2012). In tandem with REM sleep's associative nature, these findings suggest that REM sleep may enable broad integration of emotional memory traces in particular. This is admittedly a speculative function for REM sleep but it is further supported by analysis of the formal qualities of dreams collected from REM sleep. For instance, REM dreams are emotional and bizarre, and seem to combine recent and remote memories into an ongoing narrative (Antrobus, 1983; Malinowski & Horton, 2014). This is in contrast to NREM dreams which are emotionally and perceptually dry and contain more references to episodic memories (Antrobus, 1983; Kaufmann et al., 2006).

Despite such findings and theoretical speculations about an emotional memory integration function of REM sleep, interactions between emotional memory and associative access during REM sleep have not been thoroughly studied. Thus, the first goal of the present dissertation was to assess the relative influences of NREM and REM sleep, compared to wakefulness, on emotional semantic associativity. To assess associativity, we developed a new task that used either emotional or non-emotional cue-words to evoke word associates, and these word associates were assessed for their typicality compared to norms. A priming condition allowed us to assess changes in typicality of word associates provided in response to cue-words that had been primed prior to sleep. We initiated a new sleep protocol that used morning naps to assess the influence of REM and NREM sleep vs wakefulness on associational breadth. This procedure allowed us ensure that sleep episodes had similar lengths, and to select episodes containing NREM sleep only, NREM+REM sleep, and neither state (control Wake group). With these methodological innovations, we were able to demonstrate that subjects with REM sleep, but not those with NREM sleep or wake, had elevated associational breadth scores in response to emotional cue-words they had studied prior to sleep (emotional priming effect). These results

support the notion that REM sleep is specific in its capacity to broadly integrate emotional semantic memory traces (article 1).

Morning naps also enabled us to collect dream reports from NREM and REM sleep stages so that qualities of their content could be evaluated. Whether the content differences found for dream reports sampled from nighttime NREM and REM sleep are also found for nap dreams remains unclear, and comparison of NREM and REM nap dreams is all the more important in that naps are being used increasingly in studies of sleep-dependent memory consolidation. Our assessment of mental imagery measures showed that REM dreams had heightened levels of emotion and bizarreness compared to NREM dreams, verifying that content differences between these two stages were similar to findings from nighttime dream reports (article 2). The results mirror the unique associative nature of REM sleep and the selective processing of emotional stimuli during REM sleep.

While our initial findings support theoretical claims for an emotional memory integration function of REM sleep, a second goal of the dissertation was to assess to what extent disturbed dreaming may be functional (or dysfunctional) in this process. For example, nightmares are powerful unpleasant dreams associated with feelings of threat, anxiety, fear, or other negative emotions that are clearly recalled upon awakening and that arise primarily during late night REM sleep (American Psychiatric Association, 2013). Individuals suffering from frequent nightmares may have disturbed sleep patterns, both during the nightmare experience itself and potentially in its absence (Fisher, Byrne, Edwards, & Kahn, 1970; Germain & Nielsen, 2003; Marshall, Acheson, Risbrough, Straus, & Drummond, 2014; Simor, Bodizs, Horvath, & Ferri, 2013; Simor, Horváth, Gombos, Takács, & Bódizs, 2012). Such disturbances may be disruptive to sleep function, particularly in emotional memory processing.

This is supported by clinical findings that nightmare sufferers also suffer from affective disorders, including anxiety and depression, implicating a deeper relationship between nightmares and dysfunctional emotion processing (Levin & Nielsen, 2007). Nonetheless, no studies have assessed the effect of nightmares on REM sleep-dependent emotional memory consolidation. It is thus possible that nightmares interfere with the proposed function of REM sleep in the broad integration of emotional memories. In fact, the nightmare experience itself seems to reflect an interference in the integration of emotional memory. For instance,

nightmares are rather repetitive, depicting an unrelenting threat that grows increasingly powerful and persistent with increasing levels of subjective distress. Often, these themes are recurrent seemingly failing to resolve the nightmare threat (Zadra, Desjardins, & Marcotte, 2006). This pattern suggests that nightmare psychopathology may involve a resistance to—or even complete breakdown of—the associative fluidity that normally characterizes dreams (Hartmann, 2011). This pattern also complements findings in the waking cognitive literature that negative emotion restricts and slows associative access (Fredrickson, 2001; Selby, Anestis, & Joiner, 2008).

Accordingly, the second goal of this research was to assess whether the presence of nightmares interferes with REM sleep-dependent emotional memory integration. This was tested using samples of individuals who reported high and low levels of nightmare recall. Emotional associativity performance was assessed before and after REM sleep using the associational breadth task and the nap protocol that we developed and validated in Study 1. Overall, the findings failed to support our expectations of lower emotional associativity in participants with a high frequency of nightmares. Rather, our results showed that nightmare sufferers gave broader emotional semantic associations than control participants on the baseline associativity task. Further, although after REM sleep both nightmare and control groups showed similar changes in associative access in response to the priming procedure (i.e., lower associativity in response to negative cue-words and broader associativity in response to positive cue-words), one week later, the nightmare group alone maintained this altered pattern of emotional semantic access, while the control group had returned to baseline levels (article 3). This unexpected pattern of findings suggested a reorientation of our view about nightmare pathology in relation to emotional associativity and REM sleep. It raised the possibility that over longer intervals, such as a week, nightmares may interfere with the integration of emotional memory traces and prevent them from being consolidating normally.

We expected that the content of nap dreams and waking daydreams of nightmare sufferers would reflect their performance on the task, particularly imagery attributes of bizarreness and emotional intensity were predicted to follow their altered patterns of emotional semantic access. Nightmare participants were found to have heightened bizarreness and positive, but not negative, imagery in their daydreams when compared with control participants.

Further, the nightmare group had heightened body sensations in their daydreams and their nap dreams (article 4). The heightened bizarreness in the daydreams of nightmare sufferers parallels our findings that they had significantly broader associations in the baseline task and further supports claims that bizarreness in imagery reflects semantic associativity.

In general, our findings demonstrate possible benefits conferred by frequent nightmares, such as broader than normal access to emotional semantic networks. This capacity may enable increased creativity, the ability to make novel connections between seemingly unrelated or distantly related concepts. Further, nightmare sufferers exhibit enriched imagery apart from that found in their nightmares. Besides the vivid and positive waking daydreams reported here, other studies have found nightmare sufferers to report higher than average recall of positively toned dreams, such as lucid dreams (Levin, 1994; Spadafora & Hunt, 1990). Notwithstanding such advantages, the distress caused by nightmares may interfere with basic processes of emotional memory integration, and may thus contribute to the individual's risk of developing affective disorders over time.

The findings from Study 2 suggest a more complete portrait of nightmare sufferers as individuals that may benefit from a broad associative capacity and a vivid—even creative—imagination, despite suffering from nightmare distress and impaired integration of emotional memory traces over time. This led to the formulation of a third goal for this dissertation, i.e., to explore, within a novel *Environmental Sensitivity* framework, the proposition that nightmare sufferers are highly sensitive to a range of positive and negative environmental contexts, as opposed to existing models of nightmares which focus only on sensitivity to stressors. Environmental Sensitivity to both negative and positive contexts has consequences which are at times beneficial (e.g., creativity), or at times maladaptive (e.g., post-nightmare distress). Implications of such a framework for treatment approaches will be discussed; in particular, therapies focused on re-appraising negative contexts in order to promote more positive outcomes, perhaps through cognitive-behavioral approaches, lucid dream training, or mindfulness will be described.

In sum, while research supports a role of REM sleep in the associative integration of emotional memory, implications of dreaming or any potential consequences of frequent nightmares on this process have been speculative to date. In the following sections, I will review

the literature showing that sleep enhances memory consolidation, and that REM sleep in particular seems to be involved in integrating emotional experiences into broad associative networks. Following, evidence will be presented which suggests that attributes of REM sleep dreams either reflect or even function in REM sleep-dependent memory consolidation. Finally, I will review existing nightmare findings and theories consistent with the possibility that nightmare pathology may affect REM sleep memory processing. The overarching goals are to assess and clarify, first, how REM sleep and dreams function in emotional memory integration, second, whether nightmare sufferers exhibit failures in REM sleep-dependent emotional memory processing, and whether this is reflected in qualities of their dreams, and third, how our findings provide a fuller, more complete portrait of nightmare sufferers.

1.1 The role of sleep in memory consolidation

Sleep is necessary for survival. Contrary to earlier views of sleep as a period of passive rest and recovery, a growing body of empirical findings now describes multiple functions for sleep. In fact, it seems that hardly any waking function, be it physiological, cognitive or emotional, is completely independent of further processing during sleep. For instance, sleep has been implicated in a number of mental and cognitive functions, including memory consolidation and emotion regulation. Memory consolidation for different types of memory (e.g., episodic, procedural, declarative) has been associated with different sleep stages. For instance, stage 2 sleep, particularly sleep spindles and K-complexes, are often found to be associated with gains in spatial memory consolidation (Schabus et al., 2004). REM sleep, on the other hand, is often found to be involved in more complex learning and reorganization of memory (explored in detail in section 1.1.2). While there are other ways to classify memory functions vis-à-vis sleep stages (see section 1.1.2.1), the neurophysiological profiles of these differing sleep stages likely play pivotal roles in the memory consolidation functions attributed to them.

1.1.1 Sleep neurophysiology

Studying sleep in a research laboratory is accomplished with polysomnography (PSG) – a standardized, non-invasive method of recording electrical activity through surface electrodes from the scalp or skin and quantifying these recordings according to widely accepted rules for

establishing sleep stage architecture and microstructure. Typical polysomnography records consist of electroencephalography (EEG) of brain activity, electromyography (EMG) of chin muscle activity, and electrooculography (EOG) of eye movement activity.

During sleep the brain cycles though a series of successive states characterized by unique patterns of electrophysiological activity. The American Academy of Sleep Medicine (2014) provides guidelines for scoring human sleep into four stages based primarily on the frequency of brain oscillations. Stage 1 sleep is marked by a shift from alpha activity (8-13Hz) to theta activity (5-7 Hz). Stage 2 sleep is characterized by bursts of sigma activity (sleep spindles) and brief high-voltage peaks (K-complexes). Slow-wave sleep (SWS) is marked by high amplitude, low frequency delta activity (0.2-2 Hz). REM sleep is recognized by desynchronized activity with a predominance of theta activity, along with rapid eye movements and muscle atonia, particularly relatively absent chin tone (low EMG activity), though it can be further divided into tonic and phasic components. Phasic REM sleep is sympathetically driven with rapid eye movements, muscle twitches, and heart rate variability, while tonic REM sleep is parasympathetic and quiescent. Because of the uniqueness of REM sleep, sleep stages 1, 2, and SWS are often considered collectively as non-REM (NREM) sleep (Dement & Kleitman, 1957). The cycle from NREM to REM occurs about every 80-120 minutes, with SWS having longer durations in the beginning of the night, whereas REM sleep predominates in the last third of the night.

While dreaming can be reported from all stages of sleep (Nielsen, 2000), REM sleep is associated with dreaming that is more frequent, longer, more perceptually vivid, more emotional, and less related to waking life (see section 1.2). Indeed, since the first investigations of REM sleep (Aserinsky & Kleitman, 1953; Dement & Kleitman, 1957), dreaming has been closely associated with this stage of sleep.

1.1.2 Sleep is implicated in memory consolidation

Memory consolidation refers to the processes involved in strengthening memory traces and integrating recent experiences into long-term and stable memory networks. Memory has been traditionally divided into two broad categories that differ in whether access to the memory is conscious or not; consciously accessible memory is termed “declarative,” whereas

unconscious memory is termed “non-declarative” or “procedural” (Cohen & Squire, 1980). For instance, motor learning or spatial tasks rely heavily on procedural memory in that participants are not consciously aware of encoding or retrieving the specific motor actions required for the task. Rather, such memory is driven by interactions between stimuli and implicit recall, as in learning to ride a bike. Non-declarative memory is also evident in certain cognitive tasks which employ priming, e.g., the administration of one stimulus in order to unconsciously activate related cognitive material and increase speed of access to it on a later task. To illustrate, a priming effect occurs when exposure to the word “hot” unconsciously activates closely related words such as “cold” and thus increases the speed of accessing the word “cold” in a subsequent task.

Declarative, or consciously retrieved memory, is thought to consist of both semantic and episodic types of memory (Tulving, 1985). Semantic memory refers to generalized knowledge for concepts whereas episodic memory describes memory for specific events. The retrieval of an episodic memory depends on the ability to consciously recreate, in some perceptual detail, a previously experienced event as it occurred in time and space. It is generally agreed that episodic memory is critically dependent on the hippocampus and medial temporal lobe, which is where memories are initially encoded into short term storage (Cohen & Squire, 1980; Squire, 1992; Squire et al., 2004); re-activation of a hippocampal memory trace is thought to provide the spatial-temporal context that binds memory traces into a coherent episode. As an episodic memory is integrated into general semantic memory networks, the transfer of information from hippocampal areas to distributed neocortical sites allows the memory to eventually become independent of the hippocampus, and thus semantic memory lacks the contextual specificity of episodic memory (Squire, 1986). In other words, semantic memory is the result of generalization of multiple overlapping episodic events (Dudai, 2012).

These memory systems are useful for developing different types of experimental tasks and assessing the effects of sleep in consolidating the learning of such tasks. Thus, converging evidence now supports the general notion that sleep contributes to consolidation of procedural, episodic and semantic types of memory (Diekelmann, Wilhelm, & Born, 2009; Maquet, 2001; Stickgold, 2005; Stickgold & Walker, 2007; Wamsley & Stickgold, 2010).

1.1.2.1 Do NREM and REM sleep function independently or interdependently?

The past few decades have seen a surge in empirical studies attempting to clarify relationships between sleep and learning. The dual-process model was the first widely accepted model of sleep dependent memory consolidation, and used the "declarative/procedural" memory distinction as a basis for studying sleep functions. The dual-process model proposed that NREM and REM stages of sleep are responsible for distinct categories of learning, most commonly, declarative vs. procedural memory processing respectively (Maquet, 2001). A considerable number of findings supported this model, with NREM sleep being associated with improvements in diverse declarative tasks including paired-associate learning, face recognition, face-context association, and maze learning (Clemens, Fabo, & Halasz, 2005; Meier-Koll, Bussmann, Schmidt, & Neuschwander, 1999; Plihal & Born, 1997), and REM sleep being associated with improvements in procedural tasks such as mirror-tracing, visuospatial working memory, word priming, and emotional memory (Baran, Pace-Schott, Ericson, & Spencer, 2012; Gujar, Yoo, Hu, & Walker, 2011b; Wagner, Fischer, & Born, 2002).

However, a methodological limitation of these experiments is that, while the learning tasks used were supposedly dependent on recruitment of declarative or procedural memory exclusively, researchers very rarely assessed actual learning strategies of participants. That is, participants may have been applying declarative strategies to a procedural task and vice versa. Further, a number of experimental findings did not conform to this dual-process model. For example, some spatial and procedural (motor) tasks were found to be associated with NREM sleep while, conversely, other declarative memory tasks were found to be associated with REM sleep. Further, research suggests the relationship between a type of memory and the sleep stage that is beneficial for its consolidation is not a simple, one-to-one correspondence. For example, one study of motor learning (Peters, Smith, & Smith, 2007) showed that an individual's initial skill level for a learning task predicted changes in sleep microarchitecture, with both Stage 2 sleep spindles and REM sleep eye movement density being related to memory consolidation. This suggests a more nuanced approach is necessary that accounts for both the complexity of memory systems and the diversity of subjective experience, both of which may influence sleep-dependent processing.

Accordingly, a sequential model of sleep-dependent memory consolidation has been proposed (Ambrosini & Giuditta, 2001; Giuditta et al., 1995), which posits that memory consolidation is a continuous process that requires the participation of NREM and REM sleep in sequential cycles. Sequential models were developed from the most basic observations that NREM and REM sleep follow a cyclical pattern, and that REM sleep percent is consistently related to amount of NREM sleep, not to the duration of prior waking. In short, NREM and REM sleep appear to be interdependent states (Benington & Heller, 1994) and thus both implicated in memory processes. Sequential models are conceptually supported by findings indicating that certain learning tasks are dependent on both stages of sleep. For example, visual discrimination learning is associated with NREM sleep time in the first quarter of the night and REM sleep time in the last quarter of the night; the product of these two measures accounted for 80 percent of intersubject variance on a visual discrimination task supporting claims that both SWS and REM were required to improve task performance (Stickgold, Whidbee, Schirmer, Patel, & Hobson, 2000).

Several other findings also generally support sequential models of memory consolidation. In one case, the only PSG measures related to recall of word lists that were studied prior to sleep were a post-learning increase in the number of NREM/REM cycles and the time spent within cycles (Mazzoni et al., 1999); further, the experimental disruption of sleep cycles led to impaired recall of word lists. These results further suggest that sleep states may need to alternate regularly and over multiple cycles across a full night to fully function. Even more, sequential models have been extended to include the assumption that multiple nights are necessary for certain processes of memory consolidation. This assumption is supported by the finding that emotional memories become dissociated from their associated affective component after several nights of sleep but not after only one night (Deliens & Peigneux, 2014).

In sum, despite growing evidence supporting a role of sleep in memory consolidation, the contribution of specific sleep stages remains an ongoing topic of debate (Diekelmann & Born, 2010). Although dual-process models have failed to account for the range of task and performance findings, it is still relatively true that certain types or aspects of learning, i.e., declarative memory, may show more sensitivity to NREM sleep, whereas others, i.e., procedural or relational memory, may be more sensitive to REM sleep, although both types of memory may

pertain to a single memory trace. An emerging view is that the cyclic pattern of both NREM and REM sleep in a sequential and coherent manner, and even over multiple cycles and nights, is indispensable for consolidating memory traces. Several mechanisms have been proposed by which NREM sleep leads to stabilized and consolidated memory traces whereas REM sleep integrates memory and these will be discussed in the following section; specifically, that NREM sleep is largely implicated in direct memory replay and consolidation, whereas REM sleep is involved in broad memory integration and re-organization. Although none of these implicate dreaming directly, the dreams sampled from NREM and REM sleep differ in ways that parallel proposed functional mechanisms of NREM and REM sleep. For instance, NREM dreams more often replay recent episodic events, whereas REM dreams seem to form broad and novel connections between recent and past emotional experiences (Antrobus, 1983; Kaufmann et al., 2006). These parallels will be discussed further in section 1.2.1.

1.1.3 Mechanisms of sleep-dependent memory consolidation

1.1.3.1 NREM sleep memory consolidation

As mentioned, NREM sleep may function to consolidate the specific (episodic) memories of personal experiences. Several mechanisms have been proposed to accomplish this. Evidence supports two complementary processes: selective transfer and consolidation of hippocampal dependent memory traces to the neocortex, and extensive synaptic downscaling of excessive memory traces.

1.1.3.1.1 NREM sleep transfers memory from short- to long-term stores

The formation of long-term memory depends on a two-stage memory system in which newly encoded memories are gradually transferred from a temporary, short-term store into a more permanent long-term store. NREM sleep has been postulated to be the prime off-line period during which this memory transfer takes place (O'Neill, Pleydell-Bouverie, Dupret, & Csicsvari, 2010). In particular, newly encoded hippocampus dependent memories from the prior day may be transferred during NREM sleep and integrated into the neocortex, which houses intricate semantic networks of long-term memory.

Evidence for the reactivation of hippocampal memory traces during NREM sleep has been found in animal and human studies; studies in rats have shown that neuronal firing patterns recorded during the learning of a maze task are reactivated in the same order within the hippocampus during subsequent NREM, but not during REM sleep (Dupret, O'Neill, Pleydell-Bouverie, & Csicsvari, 2010). In humans, in a study in which odor was associated with the learning of an object location memory task, subsequent exposure to the same odor during NREM sleep led to increased memory enhancement after sleep. Presumably, presentation of the odor during NREM sleep led to reactivation of memory traces that had been activated during the initial odor presentation; this reactivation led to improved consolidation and memory performance following awakening (Rasch, Büchel, Gais, & Born, 2007; Rudoy, Voss, Westerberg, & Paller, 2009). Thus, off-line memory reactivation in NREM sleep seems to aid in consolidation of recent memory traces, even in a sleep period that does not contain any REM sleep. Many researchers have since suggested that NREM, and not REM, sleep is the main supporter of memory consolidation during sleep (Marshall & Born, 2007). However, REM sleep may nonetheless be involved in higher level memory reorganization (see section 1.1.3.2) or some other essential aspect of memory processing.

Further neurophysiological support for the redistribution of memory traces from the hippocampus to the neocortex during NREM sleep is found in the occurrence of slow oscillations and sleep spindles, which are generated in neocortical regions during NREM sleep in humans (Huber, Ghilardi, Massimini, & Tononi, 2004). Slow oscillations may synchronize several pathways of memory consolidation during NREM sleep; they are generated in the neocortex, but also influence the hippocampus where memory reactivation occurs, and the thalamus, where sleep spindles are generated. Both slow oscillations and thalamocortical spindles increase in prominence following learning (Eschenko, Ramadan, Mölle, Born, & Sara, 2008; Gais, Mölle, Helms, & Born, 2002) and these increases are linked to improved post-sleep memory performance (Clemens et al., 2005; Clemens, Fabó, & Halász, 2006; Girardeau, Benchenane, Wiener, Buzsáki, & Zugaro, 2009; Huber et al., 2004). Thus, during NREM sleep hippocampal memory reactivation, slow oscillations in the neocortex, and thalamocortical spindles may interactively facilitate transfer of short-term hippocampal stores into long-term memories in neocortex.

1.1.3.1.2 NREM sleep extracts semantic features from episodic memory traces

A more recent variant of the previous model, Trace Transformation Theory (TTT), takes a similar approach to sleep-dependent memory consolidation but recuperates some of the original categorical memory constituents of the dual-process model, namely, that episodic and semantic memory categories are still relevant to sleep-dependent consolidation (Dudai, 2012). The theory proposes that the hippocampus very sparsely encodes key features of episodic experience during wake, whereas neocortical circuits attempt to extract semantic features of the episode during sleep. This takes the form of a repetitive process over time, whereby multiple episodic features in numerous contexts are gradually extracted into consistent semantic features in the neocortex. In other words, based on overlap in multiple episodic memory traces, gist is extracted to form a semantic representation that is independent of any specific episodic context. The theory emphasizes that episodic traces require repeated activations to be transformed into semantic and schema-like representations. Further, it suggests that until an independent semantic memory is adequately formed, context-dependent episodic memory traces will depend on hippocampal activation (Dudai, 2012).

1.1.3.1.3 NREM sleep performs synaptic downscaling

The Synaptic Homeostasis theory proposes slow wave sleep has downscaling effects on recently encoded memories, again referring to hippocampal-dependent memory traces (Tononi & Cirelli, 2006). According to this model, a function of NREM sleep is to reduce inefficient energy expenditure by globally downscaling synaptic connections in the brain, connections which are accrued during cognitive activity in wakefulness. Synaptic downscaling would presumably occur over successive NREM cycles, systematically abolishing weak connections in memory. In this way, a core function of sleep is to reset synaptic availability in the brain (Tononi & Cirelli, 2006, 2012). This must occur because the increases in synaptic connection and strength that occur on a daily basis are not sustainable in the long term and would result in an excessive burden on the brain's resources. Thus a pattern of increased synaptic strength in wake and decreased strength in sleep is deemed necessary to maintain synaptic homeostasis (Tononi & Cirelli, 2006).

1.1.3.1.4 An integrative model: NREM consolidates relevant, and downscales irrelevant, memory traces

The Information Overlap to Abstract (IOtA) model attempts to reconcile the findings that NREM sleep aids in the long-term retention of memories and serves in systematic synaptic downscaling (Lewis & Durrant, 2011). Specifically, hippocampal-neocortical memory reactivations during NREM sleep are proposed to lead to a strengthening only of areas of overlap among newly acquired memories, e.g., neurons that code for shared memory traces would display the greatest firing rates, increasing the strength of these connections. However, reactivations of individual memory traces would not benefit from the same overlapping strengthening and it is precisely these memory traces which would then be vulnerable to synaptic downscaling. The authors suggest that this pattern of strengthening overlapping connections while erasing weak traces serves in the creation of new general schemas (similar to the TTT model), and encourages integration of new information into existing schemas.

That consolidation of general schemas takes place in NREM sleep is supported by the finding that sleep promotes false memory formation, a result of memories being integrated into a general semantic schema rather than retaining their episodic distinctiveness. Likewise, new memories are more likely to be remembered if they fit into previously formed schemas (McClelland, McNaughton, & O'Reilly, 1995; Stickgold & Walker, 2013), a process that is particularly facilitated by sleep (Lewis & Durrant, 2011). Thus, the creation of schemas may serve to strengthen relevant incoming memory traces and save them from erasure during synaptic downscaling. From this perspective, overlapping memory reactivations benefit from increased strength among themselves, along with strengthening of relevant schemas, while weak synapses are down-scaled to free up energy and space for the next day's cognitive activity.

1.1.3.2 REM sleep memory integration

One general function of REM sleep may be to integrate recent experiences into associative networks of more generalized knowledge. The unique neurophysiological state of REM sleep may allow activation of recent memory traces within an environment of increased associative cortical connectivity, thereby promoting a broad degree of memory integration (Diekelmann & Born, 2010; Hu, Stylos-Allan, & Walker, 2006; Landmann et al., 2014; Payne,

Chambers, & Kensinger, 2012; Payne, Stickgold, Swanberg, & Kensinger, 2008). Several behavioral experiments support such an associative function for REM sleep, showing a persistence of increased associative capacity immediately upon awakening from REM sleep and improved performance on associative tasks that had been primed prior to REM sleep (Cai, Mednick, Harrison, Kanady, & Mednick, 2009; Stickgold, Scott, Rittenhouse, & Hobson, 1999; Walker, Conor Liston, Hobson, & Stickgold, 2002). There are two main mechanisms proposed to subserve this adaptive function of REM sleep: that REM sleep integrates recent memory traces into existing memory networks through broad spreading activation; and that REM sleep actively re-organizes existing memory networks.

1.1.3.2.1 REM sleep integrates memory into broad associative networks

The retrieval of knowledge from memory networks relies on spreading activation, a process by which activation of a memory trace spreads to, and activates, related memories by virtue of associational closeness (Anderson, 1983). In sleep, the breadth of spreading activation may be modulated by changes in neurophysiology of the sleep state (Stickgold, Scott, Rittenhouse, & Hobson, 1999), for example, the activation of cortico-cortical connections in REM sleep (Walker & Stickgold, 2006). Broad spreading activation during REM sleep allows more distant and novel memory associations to be accessed and formed. This process could work in tandem with memories that were previously consolidated during NREM sleep, re-activating and integrating their traces into the network via broad spreading activation during REM sleep.

Walker and Stickgold (2006) proposed one model according to which newly encoded memories first undergo a stabilizing stage of individual consolidation during NREM sleep followed by an integration stage in REM sleep. The first step describes a role of reactivation and transfer of hippocampal memories during NREM sleep (as in section 1.1.3.1). The second step proposes that REM sleep integrates recent memory traces into existing associational networks. Several lines of research support a general role for REM sleep in associative thinking, including experiments studying performance on associative tasks immediately after awakening, an experimental paradigm termed the “carry-over” effect. These studies show that awakenings from REM sleep lead to more associative thinking, e.g. better performance on an anagram

solving task, or faster priming for weak word pairs (thief-wrong) than for strong word pairs (hot-cold)(Stickgold, Scott, Rittenhouse, & Hobson, 1999; Walker, Liston, Hobson, & Stickgold, 2002). Walker and Stickgold's (2014) two-step model of integrative processing is consistent with several neurophysiological aspects of REM sleep: increased levels of acetylcholine in the hippocampus, which may suppress hippocampal outflow to the neocortex, and lower levels of acetylcholine and noradrenaline in the neocortex which, along with theta wave oscillations, may all facilitate cortico-cortical connectivity. In other words, the neurophysiology of REM sleep may preferentially support the associative spread of activation through cortico-cortical connections and inhibition of static hippocampal readout (Diekelmann & Born, 2010; Power, 2004).

1.1.3.2.2 REM sleep performs schema disintegration and recombination

Another possibility is that the schemas that are presumably formed during NREM sleep undergo disintegration and re-combination during REM sleep (Landmann et al., 2014, 2015). The mechanism of spreading activation proposed in this case is similar to Walker and Stickgold's (2014) theory of associative integration, although the present theory distinguishes itself in that, in this case, REM sleep actively inhibits the typical associations within a schema, instead spreading out to uncommon and distant memory associates. In other words, closely associated memory traces are pulled apart so that more unusual associations can be formed in their place. In accordance with the IoTA model (section 1.1.3.4), the consolidation of recent memory traces into existing schemas is thought to take place primarily during NREM sleep, but the re-organization of these schemas is thought to take place during REM sleep (Landmann et al., 2015; Landmann et al., 2014). In this manner, REM sleep is related not only to the integration of newly encoded memories, but also to changing patterns of association within existing memory networks. The authors propose that this process is necessary for creativity. While the formation of schemas (in NREM sleep) has clear functions for information processing, it could interfere with creative problem solving or adaptation to novel situations, both of which might rely on novel and unforeseen combinations of memory items.

As per the results of Walker and Stickgold (2014), findings of increased associative thinking after awakenings from REM sleep support this theory. In fact, in their word priming

study, not only did REM awakenings favor weak word pairs, it also led to slower priming times for strong word pairs (Stickgold, 1999). This is of particular relevance for a theory of schema disintegration in REM sleep, suggesting that not only are remote associations more accessible, but existing schema associations are actively inhibited (or, disintegrated). In other words, the finding that strong prime word pairs are inhibited following REM sleep awakenings preferentially supports a schema disintegration model. Further, research using tasks gauging pre-to-post sleep changes in associative learning show that a REM sleep nap increases the ability to discover remote associative solutions for words that had been primed prior to the nap (Cai, Mednick, Harrison, Kanady, & Mednick, 2009). Improved performance on these types of associative tasks is thought to rely on disintegration of dominant schemas, thereby allowing access to more remote or unusual ideas, a process preferentially occurring during REM sleep. This type of thinking-out-of-the-box may be particularly advantageous for creative thinking, as well as for finding novel solutions when confronted with unusual problems.

1.1.4 Measuring sleep-dependent memory consolidation via semantic tasks

As detailed above, associational activity in memory networks is thought to be broadened in REM sleep more than in either NREM sleep or wake. This associativity can be measured through the use of semantic tasks of different kinds. Semantic networks, such as that depicted in Figure 1, are conceptualized as a set of nodes representing items in memory connected by links representing associations between these items. The learning of associations between nodes is widely accepted to be a Hebbian process (Hebb, 1949), such that when two items in memory are simultaneously active, the link between them is strengthened and the likelihood increases that activation of one node will lead to activation of others linked to it. In this manner, associative links between memory items are strengthened by the relative frequency and/or recency of their activation.

Typically, memory items with links that are conceptually closest to a given node will be activated most frequently. For example, in Figure 1, the three most common associations to the central node “brush” are “teeth, hair, comb”. During wake or NREM sleep, these associated nodes are the most likely to be activated. During REM sleep, by contrast, there is a broader spread of activation through the network, such that more distant and uncommon items are

activated. For example, the word “brush” may lead to activations of more distant items during REM sleep, such as “haircut, bristles, scissors.” From another perspective, according to Landmann et al. (2015), REM sleep may actively inhibit more proximal, common or typical memory items, such as “brush, tooth, comb”. Thereafter, upon subsequently encountering the stimulus “brush” in a period of post-REM wakefulness, those distant items will more likely be accessed, due to the relative recency of their activation by REM sleep. This is an effect of semantic priming, that is, a recently active node being made more readily accessible than nodes that have not been recently activated (Collins & Loftus, 1975; Overson & Mandler, 1987; Tulving & Schacter, 1990). Priming effects have been documented for both short (e.g., seconds, hours) and long (e.g., days, months) post-prime delays (Kvavilashvili & Mandler, 2004).

Figure 1. Semantic access in NREM and REM sleep

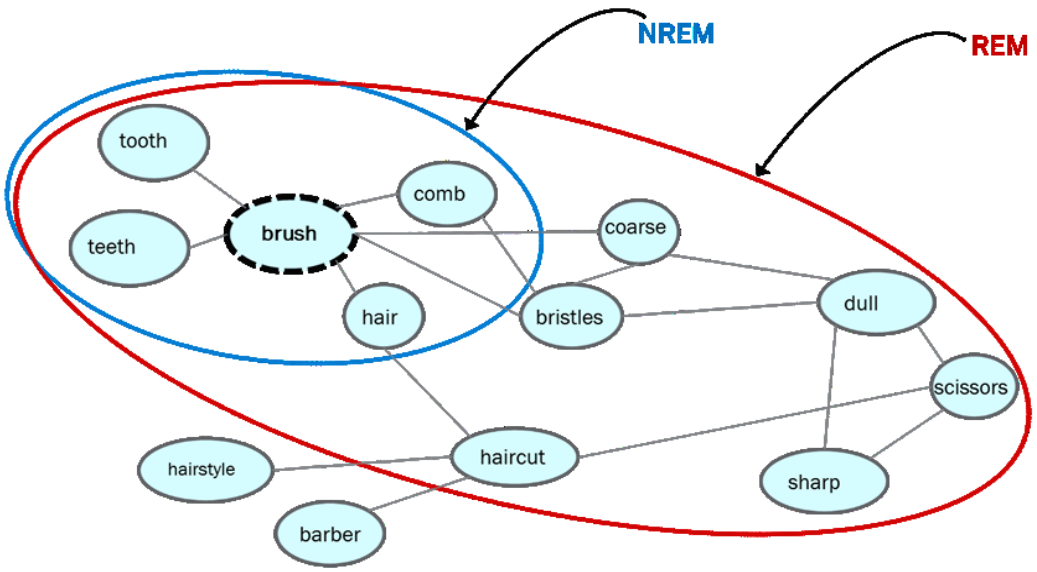


Figure 1. This example of a semantic network shows how associative access is relatively restricted during NREM sleep, whereas during REM sleep there is broad spreading activation that reaches distant, less common associations. REM sleep may even actively inhibit the close associations characteristic of NREM sleep. These mechanisms allow recent memory traces to be integrated into broad memory networks during REM sleep.

Experiments assessing associative access relative to NREM and REM sleep states have relied on assumptions about priming in memory networks; for instance, some assume that

NREM sleep enables the priming of close associates, the expectation is that such priming should continue to be accessible for some period of time upon awakening from this state. This was shown in the carry-over study, where participants awakened from NREM sleep or tested during a wake condition displayed a priming effect for closely related words (e.g., bread-butter; Stickgold et al., 1999), whereas participants awakened from REM sleep displayed a priming effect for distantly related words (e.g., bread-health). Similarly, in the anagram task, which required broad access to associative processes to find anagram solutions, sleep state-dependent performance was shown: immediate post-REM testing led to over 30% more anagram solutions than either post-NREM or wake testing (Walker et al., 2002). We interpret these findings to indicate that REM sleep activates more broad and unusual associations within semantic memory networks, and that this REM-related activation continued to modify access to semantic networks in subsequent periods of wake.

Other types of experimental evidence bolster the notion that semantic associational networks are broadened during REM sleep and that these changes may be assessed by post-awakening testing. Semantic priming prior to sleep results in improved post-sleep performance on the Remote Associates Test for participants who undergo a REM sleep, but not a NREM sleep, nap (Cai et al., 2009). In this study, prime words were presented pre-sleep, and then subsequently appeared again post-sleep embedded among the 'clues' of the individual problems of the Remote Associates Test. The pre-sleep exposure to the words presumably led to the priming of more "remote" semantic associations during the broad spreading activation of REM sleep, making them easier to access during the task problems post-sleep. Similarly, improvement in a second language, which is dependent on a broadening of semantic memory, correlates with an increase in %REM sleep (De Koninck, Lorrain, Christ, Proulx, & Coulombe, 1989). Such findings are in contrast to improvements in the learning of simple paired associates, whether semantically related (Goerke et al., 2012) or unrelated (Tucker & Fishbein, 2008), which are dependent upon the narrow network of associated memory items that is presumably predominant during NREM sleep.

In sum, semantic tasks are useful for measuring associative processing in NREM and REM sleep when used in conjunction with carry-over sleep effects. A semantic task is able to assess on a behavioral level the more general functions of NREM and REM sleep, i.e., that

NREM sleep consolidates memories relevant to existing schema, whereas REM sleep performs a broader integration and re-organization of memory.

1.1.5 Role of salience cues and emotion in sleep-dependent memory consolidation

It is generally accepted that recently encoded memory traces are selectively reactivated during sleep depending on salience cues and relevance for the future (Born & Wilhelm, 2012; Stickgold, 2013; Stickgold & Walker, 2013). In other words, not all memories benefit equally from sleep; salience cues determine whether an experience is important enough to be consolidated into long-term memory. For instance, affective arousal during encoding is thought to tag memory traces as salient for subsequent consolidation during sleep; several studies find that other motivational factors, such as reward, may similarly tag memories for consolidation (Diekelmann & Born, 2010; Hu, Stylos-Allan, & Walker, 2006; Payne, Chambers, & Kensinger, 2012b; Payne, Stickgold, Swanberg, & Kensinger, 2008). Further, NREM and REM sleep are thought to serve complementary roles in the consolidation and integration of emotionally salient memory traces. The role of emotion in selectively tagging memories at encoding to undergo sleep dependent consolidation, and empirical research demonstrating a pivotal role of REM sleep in assimilating and adapting to emotional experience, will be discussed in the following sections.

1.1.5.1 NREM sleep consolidates emotional memory traces

As mentioned in section 1.1.3, the selective consolidation and downscaling of memory traces likely occurs during NREM sleep. Further, the consolidation of emotional memory traces that have been reactivated because of salience cues ("tags") has also been linked to NREM processes. Specifically, emotional memory traces may be preferentially tagged—over non-emotional memory traces—to undergo transfer from short- to long-term stores and to survive synaptic downscaling. Research shows that sleep spindles increase following emotional learning tasks and are correlated with subsequent memory and discrimination improvement for emotional stimuli (Saletin, Goldstein, & Walker, 2011; Wilhelm et al., 2011). It may be that sleep spindles mediate the transfer of recent emotional memory traces from a short-term (hippocampus) to a

long-term (neocortex) store during NREM sleep (Buzsáki, 1996; Dudai, 2004; Landmann et al., 2015; Mölle, Marshall, Gais, & Born, 2002).

At the same time, salience cues may tag memories to survive synaptic downscaling. In one example, stimuli tagged as important for future retrieval preferentially underwent consolidation, whereas irrelevant stimuli either decayed or were actively erased during NREM sleep (Born & Feld, 2012; Stickgold & Walker, 2013), a process which may have occurred through synaptic downscaling mechanisms. In another example, auditory reactivation of a previously learned response through the use of a tone presented during NREM sleep led to better consolidation of negative, but not neutral, memories, a finding that was again mediated by sleep spindles. These findings strongly suggest that NREM sleep preferentially consolidates emotional memory traces, possibly by selecting such memories to undergo the aforementioned processes of hippocampal-neocortical transfer while targeting less salient stimuli for synaptic downscaling.

1.1.5.2 REM sleep integrates emotional memory traces

Substantial literature now indicates that REM sleep is preferentially implicated in the consolidation of emotional memory (Nishida, et al., 2009). Emotional memory consolidation has been linked to amygdala activity, which is known to be enhanced during REM sleep (Maquet et al., 1996; Nofzinger, 2005), and which likely reflects a more complex pattern of communication between amygdala, hippocampus and neocortex. All of these regions are necessary for the consolidation of emotional events (Pare, Collins, & Pelletier, 2002; Pelletier & Pare, 2004). Widespread neocortical activation in REM sleep may enable the integration of recent emotional experiences into broad autobiographical memory networks (Payne et al., 2008). In addition to evidence that the associational breadth of network access changes during sleep (see section 1.1.4), a substantial literature demonstrates that REM sleep is critical for tasks involving memory for emotional stimuli, such as the consolidation of fear and safety memories or of the negative component of complex pictures (Marshall et al., 2014; Payne et al., 2012). Neurophysiologically, limbic activity during REM sleep may support activation of emotional memory traces, within the aforementioned environment of increased associative cortical connections and broad spreading activation (Anderson, 1983).

One recent study by Sterpenich et al. (2013) demonstrated this specific link to emotional processing. Auditory reactivation of emotional face stimuli during REM sleep led to improved memory for the stimuli, but also increased false memory for unstudied, but similar, face stimuli. This finding suggests that REM sleep may favor gist processing and semantic integration within corticocortical networks specifically for emotional stimuli. Thus, while NREM sleep may promote veridical hippocampal dependent memory consolidation, REM sleep may promote associative integration of emotional memory traces which leads to more general and "schematic" memories (Diekelmann & Born, 2010).

This type of associative schematic processing is also evident in the dreams of REM sleep, where the representations of familiar people and places seem to be reconstructed schematically rather than veridically. For instance, known dream characters (e.g., family member) are rarely accurately represented in dreams, and may differ from real-life people in many aspects, including age, appearance, behavior, etc. In fact, characters who bear no resemblance to their waking life counterparts are often "recognized" simply through "feelings of knowing" (Skrzypińska & Słodka, 2014). This phenomenon suggests that emotionally relevant dream images and characters may be schematically reconstructed around an emotional or felt core, and dreamers rely on this felt sense to navigate and make sense of their dreams.

To summarize, REM sleep may be important for the integration of recent emotional memory traces within broad networks of autobiographical memory; this process may be particularly enabled by neurophysiological characteristics of REM sleep that favor the activation of emotional memory traces, along with neocortical associativity that promotes broad spreading activation and integration of memory traces.

1.1.5.3 Further implications of REM sleep in emotional processing: Emotion regulation

Besides serving in the integration of emotional stimuli, REM sleep may play a specific role in the regulation of emotion (Nielsen & Lara-Carrasco, 2007). Emotion regulation can be achieved through the modulation of arousal levels. Alternatively, it could be achieved by enabling improvements in discrimination of emotional stimuli, a process by which stimuli are appraised as threatening (or not). Or both processes may interact, with increased arousal interfering with discrimination, or poor discrimination resulting in inappropriate levels of

arousal (Phillips, Drevets, Rauch, & Lane, 2003). In any event, both types of emotion regulation are benefitted by REM sleep, which promotes recovery from prior day emotional experiences and adaptively prepares the organism for the next day's emotional onslaught.

1.1.5.3.1 REM sleep promotes recovery from stress

The first function of REM sleep occurs after an emotional experience has occurred, in an attempt to reduce the stress accumulated from the prior day. The amount of emotional stress accrued during the day therefore influences subsequent REM sleep duration and structure (Lavie, 2001). Highly stressful events such as divorce or bereavement (Cartwright, 1983; Reynolds et al., 1992; Reynolds et al., 1993) alter REM sleep patterns, decreasing REM sleep latency and increasing REM density, and suggest a causal influence of emotionally negative events on REM sleep. In a study by Germain, Buysse, Ombao, Kupfer, and Hall (2003), subjects who were told they were required to give a speech in the morning showed increases in REM sleep density across the night, but a decrease in REM counts. This pattern suggests that the stress induced prior to sleep altered patterns of REM activation. In another study, experimentally induced stress resulted in an increase in the frequency of night awakenings during REM sleep (Kim & Dimsdale, 2007).

From another point of view, sleep loss consistently results in impaired emotional expression and decreased emotional intelligence (Franzen, Siegle, & Buysse, 2008). For instance, subjects are less facially expressive, and show slower facial responses, to emotional stimuli following sleep deprivation (Minkel, Htaik, Banks, & Dinges, 2011; Schwarz et al., 2013). Subjects are also less vocally expressive, consistent with prior findings of impaired expression following sleep loss (Harrison & Horne, 1997; Killgore et al., 2008; McGlinchey et al., 2011). Besides emotional expression, subjective stress and anxiety increase following sleep loss; one night of experimental sleep deprivation increases subjects' anger and impulsivity in response to low stress stimuli (Anderson & Platten, 2011; Minkel et al., 2012). Even restricting sleep to 5 hours a night over a 1-week period causes progressive emotional disturbance and subjective emotional difficulties, as measured by mood questionnaires and daily dairies (Dinges et al., 1997). Accumulated sleep loss creates a negative shift in waking emotional activity, increasing negative and decreasing positive responses to stimuli (Zohar, Tzischinsky, Epstein,

& Lavie, 2005). This effect can be reversed by experimentally increasing the number of REM periods through repeated REM awakenings, which was shown to induce an overnight reduction in depressed mood. Such findings suggest that REM sleep may be specifically tied to emotion regulation, although there may be an intricate relationship between sleep stages and emotion regulation processing (Cartwright, Baehr, Kirkby, Pandi-Perumal, & Kabat, 2003).

In general, research demonstrates a bidirectional relationship between mood and sleep, i.e. an influence of emotionally distressing experiences on subsequent REM sleep, and also an influence of adequate (or inadequate) REM sleep on subsequent emotional arousal and perception (Lavie, 2001).

1.1.5.3.2 REM sleep recalibrates emotional sensitivity

REM sleep also contributes to emotion regulation by recalibrating the sensitivity of the brain to emotional perceptions. In other words, REM prepares the brain to accurately perceive and appropriately respond to emotional events. This process depends on precise discrimination of emotionally salient and non-salient stimuli.

Numerous studies support a role of REM sleep in this process; for instance, a REM sleep nap is effective in improving emotional discrimination, as evidenced by subjective ratings of face emotional intensities after sleep (i.e., anger, fear, happy, sad). Participants who had a REM sleep nap showed appropriate reactivity to these stimuli whereas those who did not nap showed excessive reactivity (Gujar, McDonald, Nishida, & Walker, 2010). However, not all findings support this claim, with some studies reporting preserved emotional reactivity following REM sleep and, conversely, others reporting reduced reactivity following REM sleep deprivation (Baran et al., 2012; Lara-Carrasco, Nielsen, Solomonova, Levrier, & Popova, 2009; Wagner et al., 2002). Other studies have found total sleep deprivation is associated with maintained reactivity to negative memories, while processing of positive memories is impaired (Cote, Mondloch, Sergeeva, Taylor, & Semplonius, 2014; Gujar et al., 2011b; Yoo, Gujar, Hu, Jolesz, & Walker, 2007), although it cannot be determined if these effects were due to NREM or REM sleep deprivation, or both.

1.1.5.3.3 Neurophysiological mechanisms of emotion regulation during REM sleep

During REM sleep there is an absence of noradrenergic tone, which could be responsible for restoring baseline levels of noradrenaline prior to waking (Kametani & Kawamura, 1990). In this way, REM sleep deprivation, or possibly also total sleep deprivation, may result in an increase of noradrenaline concentration (Mallick & Singh, 2011). Further, disturbances in REM quality, or repeated awakenings from REM sleep, could interfere with the naturally occurring decrease of noradrenergic tone across the night. Thus, in psychopathological conditions, alterations in REM quality or duration may be related to mood disturbances; for instance, in depression, an increase in REM quantity could lead to over-reduction in noradrenaline, resulting in affective flattening (Hamon & Blier, 2013; Southwick et al., 1999). Conversely, disorders of hyperarousal and emotional over-reactivity may result from sleep disturbances linked to a hypervigilant brain that is unable to discriminate salient from non-salient stimuli. This could be treated through pharmacological or behavioral interventions aimed at increasing REM sleep quantity or quality in order to restore next-day noradrenergic levels and emotional brain sensitivity (Taylor et al., 2008). In sum, appropriate REM duration and quality is essential for recalibrating the noradrenergic tone of the brain, and thereby to allow for appropriate levels of emotional reactivity upon awakening (Mallick & Singh, 2011).

1.1.5.4 The Sleep to Forget / Sleep to Remember hypothesis (SFSR) of REM sleep

The emotion regulation functions of REM sleep may extend to emotional memories that are integrated at this time. The SFSR theory (Walker, 2009; Walker & van Der Helm, 2009) proposes that REM sleep serves a dual function in prioritizing consolidation of emotional memories and reducing the 'affective blanket' that surrounds them. As mentioned, REM sleep has been proposed to function in consolidating and integrating recent emotional experiences into autobiographical memory networks. In other words, affective arousal that occurs during the encoding of an emotional memory may serve to tag these memory traces for subsequent reactivation during sleep (Nofzinger, 2005). Specifically, reactivation of emotional memories may be supported by limbic activity during REM sleep, and their consolidation and integration within broad memory networks may be supported by theta oscillations within extensive intra-cortical networks, allowing distributed strengthening of broad connections and effective assimilation of emotional memory traces within semantic and autobiographical networks.

While the above REM mechanisms promote the consolidation and integration of salient emotional memory traces, the unique neurochemical state of REM sleep (absence of noradrenaline) may support not only depotentiation of next day emotional reactivity, but also decoupling of emotion from memory traces that are undergoing consolidation and integration (van der Helm & Walker, 2012; Walker & van Der Helm, 2009). In other words, reactivating emotional memory traces in a brain state of suppressed noradrenergic concentrations may allow the content of the memory to be consolidated, while any associated emotional reactions are inhibited, essentially removing the 'affective blanket' while retaining the content of the emotional memory (Pace-Schott & Hobson, 2002; Walker & van Der Helm, 2009). This emotion reduction prevents an unwanted build-up of anxiety in associated memories and thus helps prevent the development of affective disorders. The theory is supported by evidence that memory is better for emotional than for neutral experiences (McGaugh, 2004), but also by observations that emotional arousal accompanying the remembering of experiences decreases over time.

This theory has been proposed as a way to explain the paradoxical fact that emotional memories are preferentially retained over non-emotional experiences, although the affective arousal associated with their recall dissipates over time. It is likely that, while arousal is an adaptive component to signal encoding tags, repeated arousal with recall would be considerably disadvantageous for the organism. Corroborating research for the theory is that REM sleep plays a role in emotional memory consolidation (Nishida, Pearsall, Buckner, & Walker, 2009; Wagner, Hallschmid, Rasch, & Born, 2006) and that brain regions active during REM sleep overlap with regions implicated in emotional functioning, particularly the amygdala, the anterior cingulate, and the ventromedial prefrontal cortex (Desseilles et al., 2006; Walker & Stickgold, 2010).

Several recent studies have attempted to further test the SFSR hypothesis. In one study, experimenters administered an emotional object memory task prior to sleep, during which they collected neurophysiological measures of reactivity including heart rate (HR) and skin conductance response (SCR). Results showed that HR and SCR measures at encoding were positively correlated with negative object memory at retrieval only for participants who slept, supporting a role of affective arousal at encoding in sleep dependent consolidation (Cunningham

et al., 2014). Further, while increased reactivity at encoding predicted subsequent memory performance, there was also a general depotentiation effect by which reactivity following sleep was reduced for both negative and neutral remembered stimuli. Another recent study used a neutral word pair task, but coupled it with induction of negative mood states prior to sleep. Again, after sleep (three nights), memory for the word pairs was improved, though the emotional tone that was originally associated with the task was reduced, suggesting that sleep served to unbind the memory content from its associated affect (Deliens, Gilson, Schmitz, & Peigneux, 2013). Finally, one key study (Sterpenich et al., 2007) demonstrated that participants deprived of sleep after memorizing emotional pictures show both reduced recall 72 hr later (poor memory) and lack of reduction in amygdala reactivity (increased emotion) when viewing the pictures a second time. These results support the SFSR hypothesis of sleep, promoting memory for emotional stimuli while decreasing affective reactivity for these memories.

1.1.6 Development of an emotional Associational Breadth (AB) task

Overall, a great deal of research supports an associative function for REM sleep, showing increased associative capacity immediately upon awakening from REM sleep and improved performance on associative tasks that had been primed prior to a REM sleep nap (Cai et al., 2009; Stickgold et al., 1999; Walker et al., 2002). At the same time, a growing literature suggests a role of REM sleep in emotional memory consolidation and regulation (Marshall et al., 2014; Payne et al., 2012). Together, these findings suggest that REM sleep is important for the integration of recent emotional memory traces within broad networks of autobiographical memory. Nonetheless, the interaction between emotional memory and associative capacity has not been thoroughly studied. For these reasons, we developed a new task to assess emotional and non-emotional semantic associativity and applied it to determine how NREM and REM sleep differentially influenced task performance.

The Associational Breadth (AB) task was designed to measure semantic associativity in a manner similar to other tasks that have been used in assessing REM sleep associativity (section 1.1.4). For instance, similar to the Stickgold et al. (1999) priming methodology, we hoped to assess the relative closeness or distance of semantic associations and, similar to the Cai et al. (2009) methods, we hoped to use pre-sleep primes to assess pre- to post-sleep changes in

performance on an associative task. Moreover, we wished to develop both emotional and non-emotional versions of the task, in order to compare the influence of REM sleep on stimuli of differing saliency.

In order to develop such a task, we found existing normative data for typical semantic associations provided in response to emotional and non-emotional words. (Altarriba, Bauer, & Benvenuto, 1999; Mednick, 1962). The norms contained 98 emotion and 100 non-emotion cue-words along with the word associations most frequently provided for each cue-word; further, imageability and concreteness ratings were provided for each cue-word (Altarriba et al., 1999). For our task, we selected only cue-words that had exactly 3 word associations provided by at least 70% of subjects. In other words, at least 70% of people responded with one of these three common word associations. The cue-words were also matched on ratings of imageability (>6/7 for non-emotion words, >4/7 for emotion words), and differed on concreteness ratings (>6/7 for non-emotion words, <4/7 for emotion words). In the end, a total of 16 emotion and 16 non-emotion cue-words were selected which met these criteria (see Table 1).

On administration of the task, participants were presented with one cue-word at a time, and asked to respond with the first three words that come to mind as being meaningfully associated.

> *The main task during this experiment is an Associative word task. You will complete this task at several different timepoints during today's experiment. For each task, you will be presented an English word and asked to respond with three word associates. When a word is presented, please type in the first THREE meaningfully associated words that come to mind. Example: If the word BLUE is presented...you could respond with "SKY, COLOR, SAD". Can you think of other possible responses?? Your responses can be associated in any way, there are no right or wrong answers. The task is timed, so try to think of three words within the thirty second time limit.*

Table 1. Cue-words and normative responses for Associational Breadth task

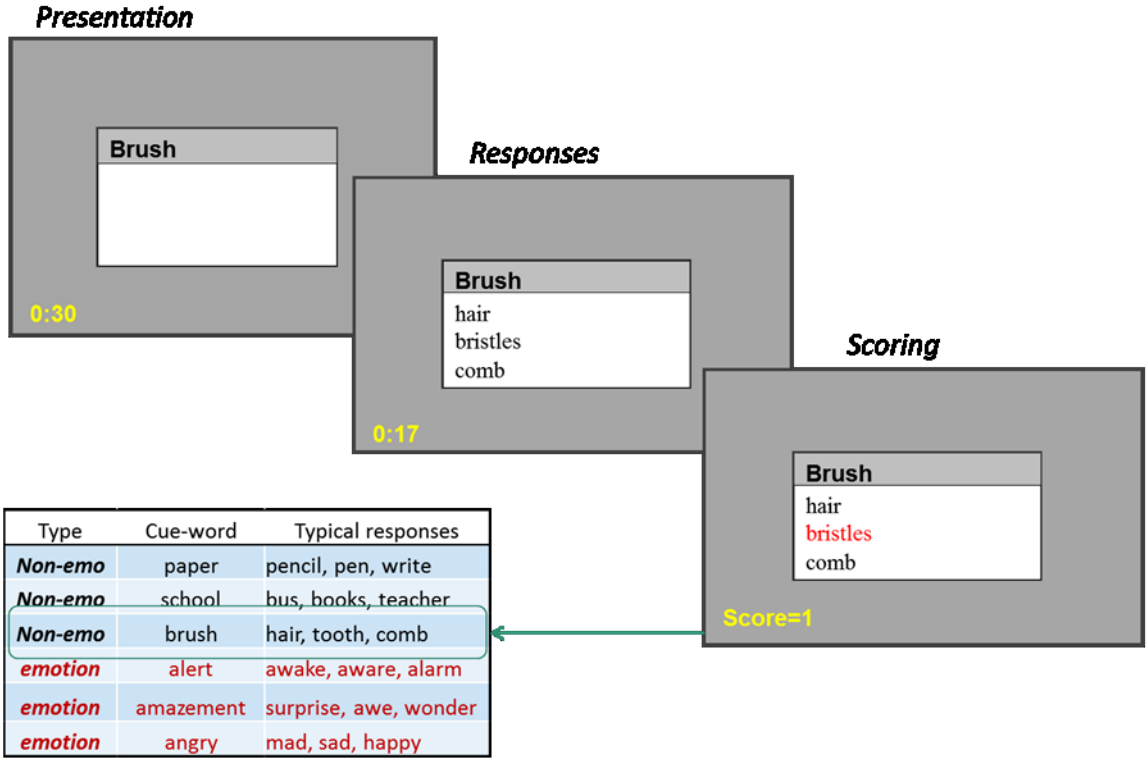
Emotion Cue-words	*Norm Responses*	***Non-Emotion Cue-words***	*Norm Responses*
awful	terrible, bad, horrible	**beer**	drink, alcohol, drunk
frustrated	angry, annoyed, mad	**bible**	religion, church, book
furious	mad, angry, upset	**brush**	hair, comb, teeth
lonely	sad, alone, depressed	**cake**	birthday, frosting, icing
miserable	sad, upset, unhappy	**calf**	cow, leg, baby
panic	attack, scared, fear	**canoe**	boat, water, river
remorse	regret, sorry, guilt	**card**	game, birthday, deck
worried	scared, nervous, concerned	**clock**	time, wall, alarm
alert	awake, aware, alarm	**dirt**	mud, ground, clean
amazement	surprise, awe wonder	**eagle**	bird, fly, bald
glad	happy, sad, mad	**egg**	yolk, chicken, scrambled
happy	sad, smile, birthday	**jewel**	diamond, ring, ruby
surprised	shocked, happy, party	**mule**	donkey, animal, horse
thrilled	excited, happy, ecstatic	**paper**	pencil, pen, write
delighted	happy, pleased, smile	**school**	bus, books, teacher
fulfilled	satisfied, complete, content	**tower**	tall, castle, high

The norms (Altarriba et al., 1999) were used to score associational breadth of responses to each cue-word; any word associate not in the norms was considered to be uncommon and scored as 1, otherwise as 0. By comparing participants' responses with the empirically derived norms, we determined relative levels of associational breadth (i.e. the frequency of uncommon responses provided by participants). Associational breadth scores were calculated separately for emotion and non-emotion cue-words.

In order to facilitate the presentation and completion of the task, it was programmed with presentation software (Inquisit 4.0.0.1, 2012), which recorded all words typed by participants and logged reaction times (RTs) between cue-word presentation and the participant's pressing 'enter' to indicate all three responses were typed (see Figure 2). For each trial, one cue-word was presented, randomly selected without replacement, and participants were required to type in their three responses. A maximum of 30 seconds was allowed to type out the 3 words; a

countdown clock on the screen displayed the time remaining for each cue-word. The next trial was administered 500 ms after the end of the previous trial for a total of 6 trials and a maximum task time of 3 minutes.

Figure 2. Associational Breadth task presentation and scoring



Type	Cue-word	Typical responses
Non-emo	paper	pencil, pen, write
Non-emo	school	bus, books, teacher
Non-emo	brush	hair, tooth, comb
emotion	alert	awake, aware, alarm
emotion	amazement	surprise, awe, wonder
emotion	angry	mad, sad, happy

Figure 2. Presentation and scoring of the Associational Breadth task. Frame 1 shows the presentation of a cue-word to the participant with a timer of 30 seconds in lower left corner. Frame 2 shows participant responses. Frame 3 shows how responses were scored in comparison with norms. In the example shown, only one response, "bristles," is considered uncommon and thus the participant receives a score of 1 on that trial.

To assess the effects of NREM and REM sleep on semantic associativity, a pre-sleep priming task was used in conjunction with the associative breadth task. Participants were instructed to memorize a sub-set of the emotion and non-emotion cue-words prior to sleep, each randomly selected without replacement from the list of experimental cue-words. These cue-words were presented for memorization in randomized order, 4 sec/word, on each of three sequential presentations. The presentation of the cue-words as to-be-remembered stimuli endowed them with the properties of semantic primes that were either emotional or non-emotional in nature. Following a morning nap with awakening from NREM or REM sleep (or

wake control), participants were asked to provide word associations to cue-words that they had memorized prior to sleep; in other words, the memorized cue-words subsequently and unexpectedly appeared as cue-words in an Associational Breadth task following sleep.

Using a nap design allowed us to administer the task at multiple times before and after sleep and thereby determine changes in associational breadth relevant to our experimental conditions, e.g. NREM, REM, or wake. Thus, we were able to determine whether memorization of stimuli prior to sleep led to changes in associational patterns after sleep, with the expectation that words studied prior to REM sleep would undergo extensive associational activation during REM sleep, leading to broader associational responses after the nap. On the other hand, participants who had had NREM sleep or stayed awake were expected not to undergo such associational activation and therefore to give more common word associations (Altarriba, Bauer, & Benvenuto, 1999). Finally, this new task allowed us to assess the effects of sleep/wake condition on emotional compared to non-emotional stimuli, with the expectation that REM sleep would preferentially integrate emotional stimuli and lead to greater increases in emotional associational breadth after the nap.

In sum, our new Associational Breadth task provides a novel measure of breadth of semantic access to both emotional and non-emotional stimuli and, in combination with a priming condition, allows us to assess relative changes in primed associational breadth following NREM or REM sleep. As reported later, we consider that this task was successful in providing experimental support for theoretical claims that REM sleep plays a role in the broad integration of recent experiences, preferentially those of an emotional nature, into long-term memory.

1.2 Dreaming

While research supports the role of sleep, and REM sleep in particular, in emotional memory integration, questions remain about whether dreams are related to or even serve an active role in this process. In general, the highly emotional, immersive, and bizarre dreams typical of REM sleep are thought to reflect the associative and emotional memory functions of REM sleep. Given such parallels, studying dreams and qualities of dream content during REM sleep may inform models of sleep-dependent memory consolidation. For instance, the

consistently embodied and multi-sensory quality of dreaming, together with its ubiquitous emotional nature, suggests that emotional memory processing during REM sleep is not only broadly associative within semantic networks, but also integrative across sensory modalities.

Nonetheless, it is important to distinguish a proposed function of sleep from the question of whether dreaming per se contributes to this function. While sleep and dreaming may be correlated phenomena, most researchers studying sleep-dependent memory consolidation do not attempt to separate their effects. Findings so far only show that dreaming is related in a general way to underlying neurophysiological states of NREM and REM sleep—with more frequent and more vivid dreaming arising in REM than in NREM sleep. And although NREM dreams tend to become more like REM dreams later in the night (likely a circadian influence), REM dreams nonetheless continue to be more emotionally and sensorially vivid (Hobson, Pace-Schott, & Stickgold, 2000; Wamsley, Hirota, Tucker, Smith, & Antrobus, 2007).

In general, some researchers consider dreams to merely reflect sleep-dependent memory processing, whereas others consider dreams to play a more integral role, particularly with respect to emotional problem solving and adaptation to stress (Cartwright, 1991; Hartmann, 1996; Nielsen, 2000).

1.2.1 Dreaming reflects the emotional and associative nature of REM sleep

1.2.1.1 Dreaming is emotional and personally significant

One major similarity between REM sleep functions and dreaming includes the generally high levels of emotion in REM sleep in comparison to those in NREM dream reports; presumably, these emotions are due to heightened limbic and amygdala activity during REM sleep (Maquet & Phillips, 1998). Emotions are nearly ubiquitous in dream reports, occurring in 70-95% of dreams reported at home or following laboratory REM sleep awakenings (Merritt, Stickgold, Pace-Schott, Williams, & Hobson, 1994; Nielsen, Deslauriers, & Baylor, 1991a). Evidence that emotional dreams may be related to ongoing REM sleep-dependent processing of recent emotional experience comes from experiments showing that emotional pre-sleep tasks, such as watching aversive films (De Koninck & Koulack, 1975) or taking stressful intellectual

tests (Cohen & Cox, 1975; Koulack, Prevost, & de Koninck, 1985; Stewart & Koulack, 1993), influence dream emotions.

Besides dealing with emotional memories, dream reports suggest that other types of important or relevant memories are also incorporated into dream content; particularly, personally significant events and current concerns of the conscious mind. In this sense, waking consciousness, thoughts, and pre-occupations can influence dream content, alongside arousal-mediated memory activations. Evidence for this is that personally significant experiences and major concerns are incorporated significantly more often into dreams than are major daily activities (van Rijn et al., 2015). Further, personally significant events, such as having an argument with a spouse, reappear in dream reports after a 1-week delay (the dream lag effect); this did not occur for major concerns, such as financial worries, or daily activities, such as writing an essay (Henley-Einion & Blagrove, 2014). The authors suggest that personally significant events are being selectively consolidated and integrated into memory networks over many nights of REM sleep.

In general, the incorporation of emotional and personally significant content into dreams may reflect REM sleep's role in integrating recent emotional and personally important memory traces into long-term autobiographical networks.

1.2.1.2 Dreaming is bizarre and associative

The associative and creative properties of dreaming have also been likened to the integrative memory functions of REM sleep (Rittenhouse, Stickgold, & Hobson, 1994). High ratings of bizarreness in REM dream reports may be indicative of increases in the associativity of semantic memory networks occurring during REM sleep (Cai et al., 2009; Carr & Nielsen, 2015). For example, Stickgold et al. (1999) concluded that their findings of increased weak word pair priming help explain the 'bizarre and hyperassociative nature of REM-sleep dreaming (p. 188)'. Further evidence that dreaming may reflect the semantic integration occurring during REM sleep is that dreaming in a foreign language is correlated with progress in waking language learning (De Koninck, Christ, Hebert, & Rinfret, 1990).

On a neurological level, bizarre dream content is thought to reflect at once the increased cortico-cortical activity of REM sleep, while also being indicative of a lack of prefrontal control;

the lack of prefrontal control inhibits self-awareness and metacognition, allowing immersion in bizarre dream experiences (Christoff, Gordon, Smith, Vartanian, & Mandel, 2011; Fox, Nijeboer, Solomonova, Domhoff, & Christoff, 2013). Hartmann (1999) similarly considered dreaming to reflect the increased connections occurring between a multitude of memory traces during REM sleep; he contrasted these with the relatively structured networks underlying conscious control (Corno, 1986) and task-focused attention (Smallwood, Obonsawin, & Heim, 2003). In this vein, low bizarreness ratings in NREM dream reports may reflect the operation of memory networks that are similar to those of waking thought and that are implicated in direct replays of episodic memories.

Even prior to recent studies that have attempted to relate dreaming to memory consolidation, some evidence emerged that bizarreness reflects increased spreading activation in semantic memory networks. Transformations occurring in dream narratives were found to follow rules of semantic association, i.e. rules governing propagation of spreading activation in semantic networks (Rittenhouse et al., 1994).

In sum, the bizarre and hyper-associative quality of REM sleep dream reports may reflect REM sleep-dependent memory processes, especially those modulating broad spreading activation and the formation of novel and unusual associations.

1.2.1.3 Dreaming is embodied and sensorially vivid

The observed predominance of sensory experience in REM dream reports—consisting primarily of visual, auditory and kinesthetic imagery—enables an extreme degree of apparent sensory immersion. Widespread sensorimotor activation parallels the fact that REM sleep is associated with the consolidation of visuo-motor and procedural learning tasks (Aubrey, Smith, Tweed, & Nader, 1999; Plihal & Born, 1999), both of which may rely on activation of sensorimotor networks, although a review of motor and procedural memory consolidation effects is beyond the scope of this review. Further, the broad integration of memory traces into more remote networks of associations is thought to rely on cross-modal integration (Frankland & Bontempi, 2005). For instance, the ventromedial-prefrontal cortex (vmPFC) plays an integrative role in strengthening semantic memories via reciprocal connections with sensory, motor and limbic cortices independent of the hippocampus; this connectivity may preferentially

occur during REM sleep. In fact, the SFSR model, which stipulates that emotional memories are integrated in long-term stores while their affective quality is stripped away, may rely critically on such multi-modal activation, as shown by the finding that overnight reduction in amygdala activity is related to an increase in vmPFC connectivity (van der Helm et al., 2011), whereas a corresponding decrease in functional connectivity across the day occurs without sleep. Thus, the multi-modal and sensory nature of dreaming is consistent with claims that broad semantic and multi-modal integration of emotional memory traces occurs during REM sleep.

Further, the multi-modal nature of dreaming fits within the growing field of embodied cognition, which suggests that the mind is inexorably linked to the body and is constantly influenced by kinesthetic sensations and bodily memories (Merleau-Ponty, 1996). Elsewhere, this is studied as the phenomenon of 'functional equivalence' between imagery and perception (Finke, 1980). For example, the processing of abstract and semantic knowledge in wake induces activity in neural regions that control sensorimotor and emotional responses during real perceptual and bodily experiences; these activations may similarly occur during sleep-dependent memory consolidation and give rise to multi-faceted and immersive dream experiences (Barsalou, 1999; Pecher & Zwaan, 2005). In this view, the physical body and its postural and kinesthetic inputs continue to influence the mind and the creation of dreams in sleep.

Researchers have indeed found evidence of kinesthetic and vestibular influences modifying dream content; for example, actual kinesthetic stimulation delivered by an inflated pressure cuff on the leg during REM sleep led to increases in bizarre and kinesthetic qualities of dream reports (Nielsen, 1986, 1993). Kinesthetic sensations and concomitant imagery in typical reports ranged from simple sensations of posture, balance, contact and movement, to more extraordinary images of bodily distortion, vibration, metamorphosis, and paralysis. There is also evidence that balance and spatial abilities are correlated with higher incidences of lucid (self-aware) and archetypal dream content, whereas balance and spatial deficits are related to nightmares frequency; these relationships imply a role for embodied cognitive activity in dreamed experience (Gackenbach, Snyder, Rokes, & Sachau, 1986; Slater & Hunt, 1997). Nielsen (1986) suggests that it is precisely such extraordinary sensations that enable the

appearance of lucidity during dreaming in that the vivid sensations engender heightened bodily attention and promotes a higher degree of awareness within the dream.

In sum, findings on the multi-modal and sensory nature of dreaming suggest that during REM sleep the ongoing integration of recent emotional experiences occurs in a broad and multi-modal fashion which includes kinesthetic and other bodily dimensions. These findings support claims that memory is inexorably embodied, even within the sleeping state. Thus, research assessing the sensory and embodied phenomenology of dreaming may inform future models of sleep-dependent memory consolidation within a more inclusive, embodied cognition perspective.

1.2.1.4 Dreaming contextualizes emotion

Hartmann (1998) proposed an integrative theory which claimed that dream images contextualize emotional experiences, i.e., created a context within which the emotions could be meaningfully expressed. This process relied on both associative linking within autobiographical networks, and the embodying of these emotional associations in vivid sensory metaphors. In other words, the contextualization theory stipulates that dream images associatively and metaphorically embody emotional experiences.

This theory (Hartmann, 1998; Hartmann, Kunzendorf, Rosen, & Grace, 2001) highlights the role of emotion in dream formation and in the contextualizing and integrating of emotional experiences by it. Dream images are proposed to be driven by the emotions associated with current concerns; the more powerful an emotion, the more powerful and salient the central image of the dream will be. The basic contextualizing role of dreaming is to represent the imagery metaphorically as a 'safe' context for the emotion. An example of a central contextualizing dream image is the "tidal wave" dream, in which a powerful wave accompanies feelings of overwhelming fear or helplessness that (presumably) originate in a waking concern with similarly intense feelings. Contextualizing depends upon a hyper-associativity of neural networks during dreaming, i.e., increased cross-connectivity among elements of the emotional concern and one or more similar past experiences. By this view, as mnemonic connections increase, emotions become less intense and the concern is progressively downscaled and integrated. The dream imagery thus provides a context within which intense emotions may be

expressed and linked constructively to other memories (Hartmann, 1995). Supporting evidence for this theory includes findings that contextualizing images are more frequent following stress (Hartmann, 2001).

Overall, the theory dovetails with the view of REM sleep as a state privileged for associatively integrating emotional memories and incorporating embodied and multi-sensorial features into dream content.

1.2.1.5 Summary

Parallels are often drawn between attributes of dreaming and the proposed functions of REM sleep; these usually implicate the broad and even multi-modal integration of emotional memory. While neurophysiological research supports the claim that emotional memory reactivation occurs automatically during REM sleep, the embodied and sensorial qualities of dreaming suggest a more encompassing view, one that considers activation of kinesthetic, affective, and sensory memory sources in addition to the standard visual and auditory modalities. This multi-modal richness, in parallel with broad associative and spreading activation, helps explain how dreaming can give rise to the uniquely bizarre and immersive dream experiences so frequently found in REM sleep. Research on these features is limited, however, so the collection and assessment of dream reports with this perspective in mind may inform future studies of memory consolidation during REM sleep, regardless of whether dreaming proves to be an active functional component of this process or not.

1.2.2 Dreaming may be functional in emotional memory processing

Beyond the many findings for REM sleep's role in memory processing, many contemporary dream theorists propose that dreaming has a specific functional role in the adaptation to stress or resolution of current emotional conflicts. That is, dream experience may play a functional role that is not explicable entirely by the neurophysiological state of sleep. For example, seeming to confront a recent stressor during dreaming may be accompanied by the recruitment of emotional problem-solving skills that are favored by the open associative nature of REM sleep, thereby providing access to a wide swath of thoughts, ideas, and emotions that may not be available in the structure of waking thought. In this way, dreaming may help in

providing creative solutions to current concerns which can then be transferred, consciously or unconsciously, to wakefulness.

Some evidence supports these kinds of claims. First, presleep stressors are incorporated into dream content, supporting the notion that dreaming plays a role in regulating daytime stress (Koulack, 1993; Stewart & Koulack, 1993). Second, overnight reductions in negative mood (e.g., unhappiness) as well as improvements in overall mood both correlate with intervening dream content (Kramer, 1993a), supporting a mood regulatory function for dreaming. Third, although some evidence shows that dreaming of a stressor may have a negative effect on mood, a more nuanced theory suggests that whether dreaming of a stressor results in improved or worsened mood may critically depend on whether or not the stressor is successfully resolved within the dream (Koulack, 1993). For instance, Greenberg, Katz, Schwartz, and Pearlman (1992) evaluated the presence of negatively toned problem in dream content and the sleep that preceded and followed it. They found that pre-sleep problems are frequently incorporated into dream content and, if the dream surrounding this incorporation presented possible solutions to a problem, then subjects felt relieved of the problem following awakening. However, dreams containing no such resolution led to a maintenance of problem-associated negative mood (Darsaud et al., 2011).

Further, while problem solving may occur within a single dream experience, it is likely that dream content influences emotional memory adaptation gradually over time and over successive REM periods, similar to a sequential model of sleep dependent memory consolidation. This is particularly relevant when the stressor depicted in the dream is related to a major life change, e.g. divorce, and thus necessitates a significant reorganization of emotional memory. Cartwright (1996) showed that recently divorced women who exhibited more negative dreams involving their ex at an intake interview were less depressed one year later than were women who had no such dreams. Thus, the incorporation of stress-related content into these dreams may have been instrumental in a gradual mood regulation process over time.

In sum, several authors suggest that dreaming promotes an adaptive function by virtue of activating unique problem solving skills; dreams which present a solution to a stressor may then assist in the resolution of current emotional conflicts or contribute to the general

improvement of mood. This process likely occurs over time, with multiple dream attempts required for successful adaptation to occur.

1.2.3 Dreaming may function independently of sleep physiology

One theory of dream function states specifically that dreaming is independent of sleep physiology. Dreaming may occur in tandem with sleep, so that REM mechanisms place constraints on the dreaming process, but the generation and control of dreams occurs independently and perhaps to its own ends. It has been proposed that the Default Mode Network (DMN)—a network of brain regions centered on the medial prefrontal cortex (PFC), medial temporal lobe structures, and posterior cingulate and associated with daydreaming, mindwandering and other spontaneous, non-instrumental cognition– is also responsible for dreaming (Daselaar, Porat, Huijbers, & Pennartz, 2010). In this view, parallels between dreaming and daydreaming would be expected and comparative study may reveal possible functions for dreaming. A recent review assessed the content of dreams and daydreams (Fox et al., 2013) and found several qualitative similarities between the two, including prevalent audiovisual sensory content (Klinger, 2009; Schredl, 2010a), emotion (Killingsworth & Gilbert, 2010; Kramer, Roth, Arand, & Bonnet, 1981), incorporation of current concerns, and an absence of meta-cognition. However, empirical study of the two types of mentation within this perspective are still lacking.

Another area of research supporting the notion that dreaming is one expression of a cross-state imagery generator deals with the phenomenon of involuntary autobiographical memory. Involuntary memory activation has been proposed to underlie all mental imagery (Rasmussen & Berntsen, 2011) and is distinct from voluntary recall, which relies on directed and controlled recall and is more frequent during waking problem solving and cognitive functions. Involuntary memory seems to arise as a function of associative and context-sensitive retrieval that requires little executive control, much like mind-wandering, daydreaming, and dreaming (Singer, 1966; Smallwood & Schooler, 2006),. The automatic spreading activation and priming of associative memory traces that takes place during involuntary memory may occur in reaction to ongoing experience and context, and may be suppressed during tasks or periods of controlled thought and memory retrieval. Such involuntary priming may then be

released during times of unfocused thought, which is typical of mind-wandering and dreaming. Some support for this idea is found in the findings that suppressing thoughts before sleep prompts their involuntary incorporation in dream content (Wegner, Wenzlaff, & Kozak, 2004) and that more than 80% of dreams contain autobiographical memory features (Malinowski & Horton, 2014).

Similarities between waking imagery and dreaming in sensory, emotional, and involuntary content (Klinger, 2009; Schredl, 2010; Killingsworth & Gilbert, 2010; Kramer, Roth, Arand, & Bonnet, 1981) also support the notion that dream imagery plays a functional role independent of the neurophysiological state from which it arises. However, dream content is distinct from waking daydreams in that dreams contain more unfamiliar settings and bizarre elements than do waking daydreams (Fox et al., 2013; Strauch & Lederbogen, 1999). Further, studies of dreaming and daydreaming have not yet compared both REM and NREM dreams with waking daydreams. Such comparisons may be useful in evaluating whether imagery is indeed independent from the established neurophysiological functions of sleep states.

1.2.4 Collection and assessment of dream content

Mental imagery reports can be obtained from NREM, REM and wake states to determine how content from these states differs, and to determine whether dreaming from NREM and REM sleep is independent from or related to waking imagery generation. The use of morning naps is ideally suited for sampling and comparing these mentation types at similar circadian phases, under similar laboratory conditions and in relation to memory tasks.

Dreams from daytimes naps are similar to those from nighttime sleep, particularly in that REM dreams of both types are both more frequently recalled and of greater length than are NREM dreams (Chellappa, Münch, Blatter, Knoblauch, & Cajochen, 2009; Palagini, Gemignani, Feinberg, Guazzelli, & Campbell, 2004; Suzuki et al., 2004). However, whether the content differences of NREM and REM nighttime dreams are also found for nap dreams requires further study (McNamara et al., 2010), which is all the more important as naps are being increasingly used in studies of sleep-dependent memory consolidation (Lahl, Wispel, Willigens, & Pietrowsky, 2008; Mednick, Nakayama, & Stickgold, 2003). Finally, because naps dreams

are more easily collected during daytime hours, daytimes naps may be especially well-suited for dream research.

For our study, a morning nap protocol was created to facilitate comparisons of NREM and REM dreams and waking daydreams under identical circadian phases and laboratory conditions. Participants were given instructions at the beginning of the experiment informing them of the daydream and nap dream report procedures. All instructions and reports were presented and completed in a standard fashion using a computer monitor placed in the bedroom, within easy reach of the bed. For the daydream procedure, participants were asked to sit in a relaxed position on the bed for three minutes, keeping their eyes closed while they let their mind be free to think or daydream about anything.

> *Before beginning the task you will be asked to sit with your eyes closed for three minutes, during which time you can think or daydream about anything. After three minutes you will hear a beep, at which point you can open your eyes and type in a 'mentation report' about any daydreams or thoughts you had while your eyes were closed. You will also answer some questions about your daydream. This procedure will be exactly the same upon awakening from your nap, when you will be asked to immediately type a dream report and answer questions about your dream.*

If participants opened their eyes during these three minutes, the computer monitor continued to display instructions to keep their eyes closed until the beep. At the end of three minutes, an 80 dB 500-hz tone was sounded and participants were instructed to immediately type in a report of whatever was going through their mind prior to the tone. Following this, participants completed a 10-item questionnaire using 1-9 response scales about specific imagery attributes such as negative and positive emotion, and bizarreness. The same procedure followed awakenings from sleep, when participants were signaled with the same 80 dB 500-Hz tone, and were instructed to immediately type in a report of whatever was going through their mind prior to the beep. They then responded to the same 10-item questionnaire.

The 10-item questionnaire consisted of several attributes relevant to the clarity of dream recall, negative and positive emotions, sensory experience, and bizarreness, all of which have been theoretically related to processes of REM sleep-dependent emotional memory integration (see section 1.3.1). Dream recall was taken from one question ("How clearly can you recall

your mental experience?") on a 1-9 scale, with 1 being no recall and 9 being complete recall. Negative and positive emotion were taken from two separate items ("What was the intensity of the most negative [positive] emotion during this experience?"; 1=not at all, 9=extremely). Sensory experience was a composite score from 3 separate items, including auditory, visual, and movement experience ("How much of a visual [hearing] [movement] component was there?"; 1=not at all, 9=extremely). Bizarreness was taken from one questionnaire item ("How bizarre was your mental experience?"; 1=not at all, 9=extremely). One item was included as a measure of subjective alertness, in order to assess any potential confounding by sleep inertia ("How awake do you feel right now?"; 1=not at all, 9=extremely). Two final items were relevant only to task performance.

The relative intensity of mentation attributes was expected to be lowest in NREM dreams and highest in REM dreams, with waking daydreams in between the two. Particularly, the emotional and bizarre attributes were expected to be highest in REM dreams, corresponding with functional roles of REM sleep in the broad integration of emotional memory.

In sum, the sampling of mental content in sleep and wake states can benefit from daytime naps. We developed a morning nap protocol, including both sleeping and waking conditions, along with daydream and dream report procedures and subjective imagery rating questionnaires. This protocol allowed us to compare mental imagery across 3 states under identical and controlled laboratory conditions.

1.3 Nightmares: Findings and theories

[modified with permission from: Nielsen, T. & Carr, M. (2016). Nightmares and Nightmare Function. In M. Kryger and T. Roth (Eds.) Principles and Practice of Sleep Medicine (6th edition).]

Given the outlined role of REM sleep in emotional memory processing, the study of individuals with intensely emotional dreams might further reveal whether habitual dreaming is related to alterations in sleep-dependent memory consolidation. Nightmares, in particular, are thought to reflect intensely negative emotional memories that can replay repetitively over many nights, and have been associated with both affective and cognitive deficits. Thus, a second goal of the dissertation was to focus on this population of disturbed dreamers in the hope of further

uncovering whether disturbed dreaming is functional (or dysfunctional) in sleep-dependent memory consolidation.

We first consider literature demonstrating that nightmares have been, and continue to be, widely accepted as a clinical symptom and thus, possibly, have no adaptive function. We then review studies showing that nightmares and a wide spectrum of other types of negative dreams are highly prevalent in the general population and, thus, that some nightmares—especially those that are infrequent, or not severe or recurrent in nature—may well play a functional role. After touching briefly on polysomnographic studies, which are inconclusive on nightmares' functionality, and neurocognitive studies, which are too scarce to permit drawing firm conclusions, we review the principal theories that address whether nightmares serve an adaptive function. These theories are multi-faceted and propose a variety of hypothetical mechanisms.

In the present context we consider the term nightmare to refer to dreaming during which intense negative emotion is in play. In this definition we subsume dreams with a variety of dysphoric emotions as well as dreams which do not immediately awaken the dreamer. This broad definition, although not shared by all writers, corresponds closely with current clinical definitions, as well as with earlier DSM-III and DSM-III-R definitions of dream anxiety attacks and anxiety dreams and is employed so that a wide swath of nightmare theories may be included in the discussion.

1.3.1 Clinical and empirical findings

1.3.1.1 Nightmares are a recognized clinical entity

Nightmares have for centuries been viewed as pathological, and are presently defined, according to the most authoritative sources, the DSM-5 (American Psychiatric Association, 2013) and ICSD-3 (American Academy of Sleep Medicine, 2014), as powerful unpleasant dreams associated with feelings of threat, anxiety, fear, or other negative emotions that occur during late night REM sleep and that are clearly recalled upon awakening. The implication of basic fear expression in nightmare genesis is indicated by the fact that fear is expressed in 65%-85% of nightmares whereas other dysphoric emotions such as anger and sadness prevail in the remainder (Robert & Zadra, 2013; Zadra, Pilon, & Donderi, 2006). This clear predominance of

fear may mean that nightmares are akin to the symptoms of other fear-dysfunction disorders, such as phobias, generalized anxiety, or social anxiety, but it may also point to a deeper involvement of fear memory, fear extinction and fear regulation systems that underlie the normal functions of emotional learning and emotional memory consolidation (see reviews in: Levin & Nielsen, 2007; Nielsen & Levin, 2007; Walker, 2010). These are not mutually exclusive possibilities of course.

The pathological context of nightmares is striking and has been reviewed in detail elsewhere (Levin & Nielsen, 2007; Spoormaker, Schredl, & van den Bout, 2006). Pathological conditions that are comorbid with nightmares range from the mild to the severe but causality between nightmares and other pathologies has not yet been clearly established. Nightmares are more frequent among those suffering from impaired sleep quality (Li, Lam, Zhang, Yu, & Wing, 2013; Li, Lam, Yu, Zhang, & Wing, 2010; Schredl, 2010b), a variety of sleep disorders (Schredl, 2009, 2010b), depressive and anxiety symptoms and neuroticism (Levin & Nielsen, 2007; Spoormaker et al., 2006), and post-traumatic stress disorder (Germain, 2013) than they are among healthy individuals. Nightmares are also reliably associated with suicidal ideation (Cukrowicz et al., 2006), suicide attempts (Sjöström, Hetta, & Waern, 2009) and death by suicide (Tanskanen et al., 2001)—independent of other psychopathologies (Cukrowicz et al., 2006; Nadorff, Fiske, Sperry, Petts, & Gregg, 2013; Sjöström, Waern, & Hetta, 2007). Frequent nightmares are also associated with the eveningness chronotype (Nielsen, 2010; Sandman et al., 2014). Nightmare-focused treatments can alleviate comorbid symptoms such as anxiety, depression and PTSD symptoms (Casement & Germain, 2014; Thünker & Pietrowsky, 2012) suggesting that nightmares may contribute to the pathology of these conditions.

Altogether, the continued description of Nightmare Disorder as a primarily fear-based disorder in the DSM-5 and ICSD-3, as well as accumulating evidence linking nightmares to various comorbid affective conditions supports the position that frequent nightmares reflect a pathological breakdown in the normal functioning of processes governing fear expression, fear memory or fear regulation. Nonetheless, despite the distress and suffering caused by nightmares, it remains possible that they also signify—at least up to a certain degree of severity—innate adaptive responses over the long term. Both possibilities, the dysfunctional and functional theories of nightmares, remain viable, albeit, unproven ideas. But in both cases, the presence of

multiple comorbid conditions among nightmare sufferers substantially complicates the determination of whether nightmares are a primary contributor to these clinical conditions and whether or not they support some kind of adaptive function.

1.3.1.2 Nightmares are ubiquitous

Large population studies indicate that nightmares are a prevalent clinical problem, but also that dysphoric dreaming is much more ubiquitous than is generally appreciated. Nightmare prevalence at a clinically significant frequency, i.e., about 1/week or more (American Psychiatric Association, 2013), varies from 0.9% to 6.8% of individuals (see review in Sandman et al., 2013). The two largest cohort studies, i.e., 69,813 participants from the general Finnish population (Sandman et al., 2013) and 87,408 7^{th}- to 12^{th}-graders from Japan (Munezawa et al., 2011), provide consistent estimates. The former study found 4.2% reported 'frequent' nightmares in the last 30 days; the latter that 6% reported nightmares 'always' or 'often' in the same time period.

But this is not the complete picture. Nightmares occur at lower frequencies among many more people, e.g., 40% of the Finnish cohort reported 'occasional' nightmares the last 30 days. A full 85% of adults report at least 1 nightmare per year (Levin & Nielsen, 2007). Occasional nightmares are not generally considered pathological; they may well be evidence of nightmares sustaining a normal, adaptive response. The widespread occurrence of nightmares is also supported by the finding that prospective measures, such as home dream logs, estimate them to be 3-10 times more frequent than do retrospective measures, such as questionnaires (Salvio, Wood, Schwartz, & Eichling, 1992; Wood & Bootzin, 1990; Zadra & Donderi, 2000). In addition, there is a much wider spectrum of disturbed and dysphoric dreams, of which nightmares are clearly a part and from which they have not been clearly distinguished (Levin & Nielsen, 2007; Nielsen, 2011). To illustrate, many types of disturbed dreams have been described for, e.g., bereavement (Kuiken, Chudleigh, & Racher, 2010), pregnancy (Lara-Carrasco, Simard, Saint-Onge, Lamoureux-Tremblay, & Nielsen, 2014), following trauma or brain surgery (Solms, 1997), after consuming or withdrawing from various drugs, or in tandem with many mental, physical and sleep disorders (see reviews in Nielsen, 2011; Solms, 1997). Bad dreams, in particular, have been distinguished from nightmares in that they do not lead to

awakenings, are less emotionally intense but as likely to contain negative emotions (Robert & Zadra, 2014). Bad dreams occur up to 4 times more frequently than do nightmares (Robert & Zadra, 2014; Zadra & Donderi, 2000). Bad dreams and nightmares together occur on average at a rate of about 40/year among healthy university students (Zadra & Donderi, 2000) and constitute 13.7% of all dreams reported by 572 subjects (n=9796 dreams; Robert & Zadra, 2014). That bad dreams are thematically similar to nightmares (e.g., physical aggression) yet more likely to resolve positively (38%) than nightmares (22%; Robert & Zadra, 2014), suggests that they may be more functional in regulating emotions than are nightmares. Beyond bad dreams, negative emotions constitute from 66% to 80% of all dream emotions in home dreams (Hall & van de Castle, 1966; Strauch & Meier, 1996).

In sum, while nightmares are clearly recognized as a clinical entity, the ubiquity of nightmares as part of a wider, still insufficiently articulated, spectrum of disturbed and dysphoric dreams supports the possibility that they may play a role in cognitive-emotional regulation or processing of emotional memories; a role that may diminish as the nightmares become more severe and disruptive.

1.3.1.3 Sleep PSG findings for nightmare sufferers are inconclusive

Polysomnography (PSG) has revealed several sleep-dependent memory functions, with memory improvements having been linked to both the proportions of sleep stages and microstructural sleep features such as spindles and rapid eye movement density (Alger, Chambers, Cunningham, & Payne, 2014). REM sleep, in particular, has been linked to the processing of emotional stimuli, such as consolidation of fear and safety memories (Marshall, Acheson, Risbrough, Straus, & Drummond, 2014) or of the negative component of complex pictures (Payne et al., 2012b), and to modulation of emotional reactivity (Alger et al., 2014). In light of such advances, the PSG features characterizing nightmare sufferers—and in particular their REM sleep features—may provide clues to nightmare functionality.

Unfortunately, PSG studies pertaining to nightmares and nightmare sufferers are few and inconclusive. Two studies of nightmare episodes (Fisher, Byrne, Edwards, & Kahn, 1970; Nielsen & Zadra, 2005) both revealed signs of REM sleep activation (e.g., HR increase) which can be attributed autonomic arousal that would be expected to accompany fear. On the other

hand, in a surprising 60% of cases (Fisher et al., 1970) this expected autonomic arousal was not observed, raising the possibility of a dampening of affect expression during nightmares (see later). Other studies have found more eye movements per minute and shorter breath times for dreams that are high vs. those that are low in anxiety (Goodenough, Witkin, Koulack, & Cohen, 1975). For the habitual sleep of nightmare sufferers, no consistent patterns of PSG abnormalities in either micro- or macro-structure have been established. Some studies find REM-specific abnormalities, such as increased skipping of early REM periods, increased REM latency and cycle length, more REM periods (Nielsen et al., 2010b), and increased spectral power in the high alpha range (10-14.5 Hz; Simor, Horváth, Ujma, Gombos, & Bódizs, 2013b), while others report changes in NREM sleep such as low alpha power (Simor et al., 2013b), reduced CAP A1 but increased CAP A2 and A3 subtypes (Simor, Bodizs, Horvath, & Ferri, 2013a), and reduced NREM (Simor, Horváth, Gombos, Takács, & Bódizs, 2012a). Yet other studies report global changes such as more frequent periodic leg movements (Germain & Nielsen, 2003b), more fragmented sleep (Fisher et al., 1970; Newell, Padamadan, & Drake, 1992), longer sleep latency, more nocturnal awakenings (Simor et al., 2012a), and increases in the normalized low frequency component of the heart rate during recovery sleep after REM sleep deprivation (Nielsen et al., 2010a). These findings are discrepant, but could be considered to reflect an increase in arousal during the sleep of nightmare sufferers, be it expressed as leg movements, nocturnal awakenings, or alpha oscillations. This notion fits with the subjective experience of increased emotional and physical arousal during nightmares. However, increased arousal in sleep is not a highly specific correlate of known sleep-related functions and also does not account for why sometimes nightmares are triggered and sometimes they are not.

Overall, the inconsistencies and lack of replication studies in the sleep literature do not yet allow reliable links to be made between nightmares and known memory or emotion regulation functions of sleep.

1.3.1.4 Neuropsychological studies of nightmare sufferers are scarce

The testing of cognitive or neuropsychological attributes might illuminate the functional status of nightmares by revealing specific waking state deficits or advantages that are characteristic of this population. This is analogous to how such testing has revealed relationships

between sleep-related memory consolidation and brain conditions like functional memory impairment (Puetz et al., 2011) or mild cognitive impairment (Westerberg et al., 2012) or between cognitive competency (IQ) and sleep spindles (Gruber et al., 2013). However, research on nightmares is scarce. One study (Simor, Pajkossy, Horváth, & Bódizs, 2012b) of nightmare sufferers and controls revealed some performance deficits and some advantages on prefrontal and fronto-limbic measures of executive functions and emotion regulation. Nightmare sufferers showed general slowing on the Emotional Stroop, longer reaction times on the Emotional Go/NoGo, and slightly lower fluency and substantially higher perseveration on Verbal Fluency. On the Color-word Stroop, however, nightmare subjects committed fewer errors than controls for incongruent word/color pairings, suggesting superior functioning on tasks implicating dorsolateral prefrontal and dorsal anterior cingulate regions (Simor et al., 2012b). Our attempt to replicate the elevated Verbal Fluency perseveration finding (Saint-Onge, Blanchette-Carrière, Paquette, & Nielsen, 2014) was only partially successful; we failed to find a difference between nightmare and control groups, we did show a positive correlation between perseveration and nightmare severity. These findings are thus consistent with the possibility of a dose-response relationship between frontal deficits and nightmare severity. Finally, neuropsychological studies of brain injuries and disease (Silvestri & Bromfield, 2004; Solms, 1997) reveal that nightmares with recurrent stereotypical themes are often associated with seizure disorders, and usually involve lesions in the right temporal lobe (Solms, 1997, p. 65). Recurrently themed nightmares that replay the trauma are also characteristic of PTSD patients (Mellman & Pigeon, 2005). This particular type of nightmare, then, may reflect a fundamental neural dysfunction.

1.3.2 Nightmare theories

Theories surrounding the potential cause, and subsequent effect, of nightmares on human function have remained contentious since at least the time of Freud (1900). Freud, in fact, initially considered nightmares ('anxiety-dreams') to conform to his theory that dream function in general is to repress expressions of unacceptable unconscious impulses (Freud, 1900, chap 4, para 2). But he also admitted that nightmares challenge this theory by recognizing a repetition compulsion in the more severe 'war neurosis' nightmares and, later, other 'immoral' dreams for which the dream work mechanisms of censorship had broken down (Freud, 1943). In more recent times, with growing emphasis on the medicalization of nightmares (American Psychiatric

Association, 2013), as well as evidence linking nightmares to psychopathological conditions, beliefs that nightmares are dysfunctional are widespread. Two such theories (Kramer, 1991; Stein, 1965) single out nightmare awakenings as evidence that dreaming's function has failed. A third (Nielsen & Levin, 2007) considers failures to regulate fear extinction during dreaming as responsible for dysfunction.

Although a number of studies report evidence for genetic (Coolidge, Segal, Coolidge, Spinath, & Gottschling, 2010) and personality risk factors for nightmares, such findings typically have not been formalized into theories of nightmares, and so will not be considered further here. Also, *The Interpretation of Dreams* (Freud, 1900) heavily influenced many later nightmare theorists, e.g., Jones' (1910) theory that anxiety-dreams contain unconscious sexual impulses, and remained influential among psychoanalytic thinkers for half a century. Only three theories that diverge in important respects from classical psychoanalytic thinking, Kellerman (1987), Fisher (1970) and Palombo (1978), are reviewed here. Most of the theories we consider share a general assumption that nightmares are implicated in processes of emotion regulation. We present these theories separately to highlight the more specific mechanisms of emotion regulation that they bring forward and to summarize the available empirical findings that support or refute each.

1.3.2.1 Nightmares may represent temporary failures in emotion regulation

Though the following theories posit a variety of mechanisms by which dysphoric dreams function in integrating and/or down-regulating emotional memories, the awakening associated with a nightmare is typically seen as a temporary failure in this process. Further, it is suggested that if emotion regulation is unsuccessful on a given night, further attempts on subsequent nights will appear in a pattern of recurrent REM nightmares, as is characteristic of PTSD (Walker & van Der Helm, 2009).

1.3.2.1.1 Emotion-defense regulation

One neo-psychoanalytic theory (Kellerman, 1987) diverged from Freud (1900) in attributing nightmare awakenings to ego defense mechanisms that fail to contain the over-activation of specific types of emotions. Nightmare awakenings are purportedly triggered by 8 basic emotion types: joy, acceptance, surprise, expectation, anger, disgust, sorrow, or fear

(Plutchik, 1962), each of which produces a distinctive nightmare theme and, frequently, characteristic behaviors upon awakening. For example, fear could lead to a terror nightmare with overt locomotion or speech on awakening; anger could lead to a rage nightmare with fist-clenching; sorrow could lead to a grief nightmare with copious crying; and joy—paradoxically perhaps—could lead to a 'pleasure' nightmare with nocturnal orgasm. This eight-fold structure of nightmare themes was extended to include not only ego defense mechanisms—one type per theme—but to more general attributes of personality structure, cognitive orientation, psychosomatic organ systems, etc. (Kellerman, 1987; Table 18.1). An intriguing component of this theory is that every nightmare is thought to contain an element of fear to the extent that there is resistance to fully express a predominant emotion while dreaming, e.g., a fear of letting anger amplify to overt rage or of letting joy/pleasure amplify to the point of orgasm.

Despite its clarity and accessibility, this theory has not been tested empirically and has fostered surprisingly little research; Google Scholar identified only 10 citations of the work over 27 years and none were empirical tests of the theory. The theory is, however, generally consistent with current definitions of nightmares as including emotions other than fear as well as studies showing that awakenings from nightmares and other dysphoric dreams are often accompanied by dream-enacting behaviors in both parasomnias like RBD (Schenck, Hurwitz, & Mahowald, 1988) and among the general population (Nielsen, Svob, & Kuiken, 2009).

*1.3.**2.1.2 Failures in 'mastering' stress***

While early theories of dream function emphasized roles for REM sleep and dreaming in facilitating adaptation to stress (see Section 1.3.3), most of these dealt only marginally with nightmares. Thus, despite evidence that presleep stressors are incorporated into dream content or increase dysphoric dream emotions (Breger, Hunter, & Lane, 1971; Cohen, 1972; De Koninck & Koulack, 1975; Foulkes, Pivik, Steadman, Spear, & Symonds, 1967), findings were generally interpreted to indicate how normal dreaming was able to 'master' (Breger et al., 1971) or 'assimilate' (Jones, 1970) daytime stress rather than to explain how stress might trigger nightmares or how nightmares might modify stress. One exception to this trend was a focus on the possible role of nightmares in 'war neurosis' (Greenberg, Pearlman, & Gampel, 1972), now

known as PTSD, which considered dream function to be mastery of stress and nightmares to reflect continuing attempts to master a trauma.

Another exception was the disruption-avoidance-adaptation theory (Koulack, 1991; Wright & Koulack, 1987) which hypothesized that dreaming enables stress adaptation by its oscillation between two distinct functions: mastery and avoidance. Dreams about unresolved disturbing events are considered *mastery dreams* and have the potential to disrupt sleep—as in the case of awakenings from nightmares. Mastery is hypothesized to occur by a type of creative emotional problem-solving that draws on memories of similar, yet successfully resolved, past situations. Emotional mastery is favored by the lack of interruption, disregard for social acceptability, and free-flow of ideas, thoughts and emotions unique to dreaming. If dreams are too disruptive, however, awakenings and other sleep disturbances may result. *Avoidance dreams* prevent mastery attempts, and thus sleep disruption by various processes, e.g., presenting dream emotions or specific contents that have no apparent relationship to the waking stressor. Oscillation between mastery and avoidance dreams continues, within and across nights, until adaptation in attained. Nightmares, because they disrupt sleep, are evidence of failure of both mastery and avoidance functions.

*1.3**.2.1.3 Desomatization***

Fisher and colleagues (1970) found that some REM sleep nightmares were not accompanied by the autonomic activation that would be expected for the negative emotions reported. In 60% (12 of 20) of their recorded nightmares, emotion-related autonomic activation, as measured by heart rate, respiratory rate and eye movement activity, were not seen. In other nightmares, such activity occurred only in the last few minutes of the REM episode. Similar findings were reported in a more recent study (Nielsen & Zadra, 2005). This apparent separation of seemingly fearful dream imagery from its expected autonomic correlates prompted the notion of REM dreaming as a mechanism for `…tempering and modulating anxiety, for desomatizing the physiological response to it…[for] abolishing or diminishing the physiological concomitants' (Fisher et al., 1970, p. 770). This desomatization mechanism was thought to help protect REM sleep, to assuage anxiety during dreaming, and to decrease the degree of disruption that occurs once an awakening does occur. This serves to prevent the self-perpetuation of

anxiety and assist in the mastery of traumatic memories—even after awakening (Fisher et al., 1970). A breakdown of the mechanism is suggested by intense autonomic activity while dreaming, as occurred in 40% of their recorded nightmares.

Similar desomatization notions have occurred sporadically in the literature, and slightly different desomatizing mechanisms proposed. A short note on a desensitization function of dreaming (Beavers, 1973) and an empirical study on an anxiety-extinction function of nightmares (Haynes & Mooney, 1975) were both published shortly after Fisher et al.'s work. These authors suggested that nightmares facilitate extinction through repeated exposure to fear-inducing stimuli (like implosive therapy), but their own findings did not support the hypothesis (Haynes & Mooney, 1975). Others have pointed to specific physiological mechanisms of REM sleep that might be responsible for desomatization. These include REM sleep eye movements desensitizing affect by a mechanism similar to that of eye movement desensitization and reprocessing (EMDR; Shapiro, 1989; Stickgold, 2002); REM sleep atonia desensitizing the somatic component of negative affect by repeatedly blocking kinesthetic feedback during negative dream imagery (Nielsen, 1991; Nielsen, Kuiken, & McGregor, 1989); and, in a related theory, the repeated pairing of dysphoric dream imagery and REM sleep atonia desensitizing anxiety in a manner analogous to systematic desensitization therapy (Perlis & Nielsen, 1993). In all such models, negative affect is considered to be implicated in desensitization up to a certain threshold; this threshold is clear when it is the point of waking up (analogous with flooding therapy) but otherwise remains undefined in most cases.

In addition to evidence replicating Fisher et al's observation of desomatized nightmares (Nielsen & Zadra, 2005), there is evidence that dream emotion may be inhibited by REM sleep processes related to the orienting response (Nielsen et al., 1989) or modulated by two REM sleep mechanisms associated with threat-fear and loss-sadness (Kuiken et al., 2010). Desomatization theories imply that negative emotion should be progressively reduced over time, especially within a single dreaming episode. Two studies suggest, in fact, that dream emotion becomes more negative over time (Merritt et al., 1994; Nielsen, Deslauriers, & Baylor, 1991b).

In sum, desomatization theories propose mechanisms of emotion regulation during dreaming and nightmares by which strong emotion is down-regulated by its repeated pairing

with processes such as autonomic inhibition, muscle atonia, eye movements, or orienting reactions.

*1.3.**2.1.4 Mood regulation***

The mood regulatory theory posits an emotion regulation function for dreaming (Kramer, 1991, 1993b) and is similar in many respects to desomatization approaches. It assumes that a cardinal characteristic of REM sleep is a 'surge' of affective arousal that unfolds over the REM episode. The surge consists of a progressive increase and subsequent plateau in autonomic arousal as indicated by heart and respiratory rates, eye movement amplitude and density, and limbic system activity, among other markers. Dream content 'contains' these surges by reducing the intensity and variability of the associated emotions. This is achieved by *progressive-sequential* patterns of dream content that unfold over successive REM periods and that facilitate emotional problem-solving. The progressive-sequential dream pattern is distinguished from a *repetitive-traumatic* pattern during which an emotional conflict is simply stated and restated without evidence of adaptive change. Nightmares contribute to problem-solving up to a point where the capacity for assimilation of emotional surges is exceeded. Similar mood regulation theories that consider nightmares to function as a coping mechanism for stress have been proposed by others (Cartwright, 1996; Picchioni et al., 2002).

The physiological assumption that REM sleep is surge-like in nature remains to be demonstrated empirically. However, the frequency and intensity of nightmares is associated with both increasing daily stress and increasing coping efforts (Picchioni et al., 2002). Stress that is induced either experimentally (difficult intelligence test; Koulack et al., 1985) or naturally (earthquake; Wood, Bootzin, Rosenhan, Nolen-Hoeksema, & Jourden, 1992) leads to an increase in incorporations of the stressor in later dreams and nightmares. Consistent findings were also reported (Cartwright, 2005; Cartwright, Luten, Young, Mercer, & Bears, 1998) by which high pre-sleep depression scores were associated with more dysphoric dreams from the first REM period—but not with sleep physiology variables.

In sum, mood regulation models posit mechanisms for down-regulating intense emotions via the nature and structure of dream content; this may require the regular coupling of emotional

surges with a problem-solving dream structure unfolding over time or the timing of negative dream emotion early in the night.

*1.3.**2.1.5 Fear extinction***

A recent theory (Levin & Nielsen, 2007; Nielsen & Levin, 2007) ascribes a fear memory extinction function to dreaming and explains nightmares as a perturbation of this function. Cognitive and neural levels of description are articulated.

Cognitive level explanation. Fear extinction entails the activation of fear memory elements that are isolated and removed from their episodic contexts, the recombination of these into novel 'here-and-now' simulations of reality, the expression of alternate emotional reactions to this virtual context and, ultimately, the production of new *fear extinction memories*. Fear extinction memories provide a sense of 'safety' and thus compete with and, if consolidated, supersede the original fear memories. Fear extinction memories are realized by coupling fear memory elements with realistic non-aversive contexts that are incompatible with fear by a mechanism obeying Pavlov's (1927) principles of fear memory learning and extinction (for review see VanElzakker, Kathryn Dahlgren, Caroline Davis, Dubois, & Shin, 2013). Nightmares occur as a result of disruption of this mechanism. For example, if an entrenched fear memory resists recombining with new contexts, as might be the case for nightmares with recurrent themes, new extinction memories may not be formed. Or, if an extinction memory is not properly consolidated, an original fear memory may be reinstated (Vervliet, Baeyens, Van den Bergh, & Hermans, 2013). Temperament may also interact with these basic extinction processes, especially one's susceptibility to *affect distress,* which could amplify the emotional responses produced.

Neuronal level explanation. At the neural level, fear extinction is supported by a network of at least 4 regions that control the representation and expression of emotions in both sleeping and waking states: the amygdala (Amyg), the medial prefrontal cortex (mPFC), the hippocampal (Hip) complex and the anterior cingulate cortex (ACC). Normally, these regions interact with larger integrated networks such as the default mode network (Fox et al., 2013) or the extended mirror neuron system (Molenberghs, Cunnington, & Mattingley, 2012). Each region controls a set of extinction processes defined at the cognitive level of explanation. During nightmares, the

Amyg may be hyper-responsive to fear-related memory elements portrayed in the dream, while processes in the mPFC, the Hip or the ACC that normally down-regulate Amyg activity may be disrupted. The result is the abnormally intense activation of fear. This situation parallels empirically-supported models of PTSD pathology (Rauch, Shin, & Phelps, 2006). Affect distress, linked to ACC activity, is shaped by the emotional history of the individual (e.g., early adversity) but also to pain-related distress, social rejection, and difficulties with emotional expression (see review in Eisenberger, 2015).

The fear extinction theory is grounded in a considerable amount of neuroscience research but has not yet generated a great deal of new findings. One test of the theory (Simor et al., 2012b) used neuropsychological tests to assess involvement of frontal brain regions and supported the theory to the extent that frequent nightmare sufferers showed poorer performance on verbal fluency perseverations. These findings were partially replicated with a cohort of French-speaking participants (Saint-Onge et al., 2014).

1.3.2.1.6 Cognitive avoidance and the limits of fear extinction: Recurrent nightmares

Spoormaker (Spoormaker, 2008) proposed a variation of the preceding theory to explain fear extinction failures in the subclass of nightmares with recurrent themes. The recurring storylines are stipulated to be "scripts" in memory that are easily activated by ongoing, neutrally-toned dreaming and whose specific contents vary as a function of this prior dreaming. Nightmare scripts may be based upon real traumatic memories or may develop over time with repeated emotional stress, particularly if stressors are habitually responded to in a way that develops and reinforces the underlying script. Cognitive avoidance is the key mechanism by which occasional distressful nightmares may become recurrent. After awakening from such a non-pathological nightmare, avoidance strategies (e.g., trying not to think about or remember the nightmare) lead to a failure of fear extinction as well as a reduced likelihood that the root script will be integrated into autobiographical memory or that alternative responses to the nightmare script will be discovered. In detailing the limits of fear extinction processes, this model clarifies the pathological aspect of nightmare experience.

The theory's emphasis on recurrent themes fits well with the fact that the plot lines of many nightmares are, indeed, recurrent. An unpublished study found that of all nightmares

reported by 188 college students, including those that were only occasional, 60% contained a recurrent storyline (Spoormaker, 2008). Among participants with a clinical nightmare problem (at least 1/week), 91% claimed that their nightmares possessed recurrent storylines. The inherent dysfunctionality of recurrent nightmares also fits well with the finding that recurrent dreaming more generally is associated with poorer well-being (Brown & Donderi, 1986).

1.3.2.2 Nightmares may serve specific functions

1.3.2.2.1 Threat Simulation

This evolutionary theory (Revonsuo, 2000) suggests that the purpose of dreaming—including nightmares—is to provide a realistic (virtual) environment for confronting threatening situations and practicing threat perception and threat-avoidance skills. Repeated threat simulation over time increases the probability of successfully coping with real threats in wakefulness and confers a survival advantage to our species. The threat simulation mechanism is fully activated, and thus produces more dreams with threats, when the individual is exposed to heightened levels of daytime threat (e.g., living in a war zone). The high prevalence of dysphoric dreams and nightmares supports the theory as these commonly portray threats. Thus, nightmares of being attacked or chased are considered functional to the extent that these provide opportunities to identify threatening situations that might be met in real-life and to practice adaptive reactions to them. Research supporting the theory includes dream content analyses showing that college students report frequent threatening dreams that are both severe and realistic (e.g., aggression, misfortune themes), and during which appropriate responses are enacted by the dreamer (Revonsuo & Valli, 2000). Further, children subjected to high levels of threat (trauma), in fact, do dream more often and more intensely of threatening events (Valli, Revonsuo, Pälkäs, & Punamäki, 2006). Arguments against Threat Simulation theory claim that the threats created in dreams are too often unrealistic (Malcolm-Smith & Solms, 2004) and that the dreamer is too often unable to react successfully to the threat (Malcolm-Smith, Solms, Turnbull, & Tredoux, 2008). Realistic threats appear in less than 15% of recurrent dreams (Zadra, Desjardins, & Marcotte, 2006), and in only 8% of undergraduates' home dreams (Malcolm-Smith & Solms, 2004). The experiencing of threat dreams also does not correlate with actual adaption to threatening events, as in the case of PTSD, where re-experiencing

nightmares are often debilitating. Further, the occurrence of nightmares before or after trauma exposure is often a risk factor for developing PTSD (Mellman & Pigeon, 2005).

1.3.2.2.2 Post-awakening Adaptations

A number of approaches consider nightmares to be functional to the extent that reactions after waking up may play a homeostatic or adaptive role. One type of theory suggests that a post-awakening function can be automatic. The *information-processing* or *memory cycle* theory (Palombo, 1978, 1983) is a neo-psychoanalytic approach based on the notion that dreaming's function is incorporation of important new experiences into long-term memory, i.e., the affective integration of new with old memories. Anxiety dreams that produce awakenings have a particular functionality in that they 1) signal a failure of normal affective integration, but 2) allow waking state processes to modify memory sources of the original anxiety dream. This leads to a modified, *correction,* dream the following night. Associating an anxiety dream with other thoughts, feelings and memories essentially integrates the latter new sources of information with the original sources, and provides new, more adaptive, memory sources for the correction dream. This post-awakening integrative function may be automatic and preconscious, resulting simply from 'having the dream in mind' during the day, or it may be deliberate, either by intentional reflection on the dream during waking, or by the aid of a therapist. In either case, the corrective feedback leads to a permanent, adaptive reorganization of emotional memory structures. Recurrent anxiety dreams are thought to reflect a failure of affective integration and a failure of the correction dream to correct it. The theory has been subject to very little empirical investigation and is supported only generally by evidence that REM sleep is linked to emotional regulation.

A second type of post-awakening theory also considers that using dreams in a self-reflection or therapeutic context leads to biological adaptations but the mechanisms for such adaptations are not typically specified. One general goal of some such approaches is to alleviate the suffering associated with the nightmares using pharmacological or behavioral approaches (Nadorff, Lambdin, & Germain, 2014), but another common goal is to use the nightmares as a source for uncovering focal emotional conflicts which can then be addressed therapeutically. In this case, nightmare-focused therapies have been documented for a diversity of emotional

conditions such as bereavement (Armstrong, 2012), drug dependencies (Johnson, 2012) and general psychotherapy (Heaton, Hill, Hess, Leotta, & Hoffman, 1998).

1.3.2.3 Summary of existing theories

Science still remains divided in many ways on whether the darker side of dream experience serves a purpose. Nightmares and other disturbing dreams have been clearly delineated as a pathological condition that is comorbid with many other illnesses, a view that is broadly consistent with the notion that nightmares are either non-functional or dysfunctional symptoms. However, their nearly ubiquitous existence in the general population, including evidence for a much wider spectrum of disturbed and dysphoric dreams (e.g., bad dreams), points to the likelihood that some nightmares may, in fact, be a component of cognitive-emotional regulation or emotional memory processing functions. Nightmares that are neither too frequent, too severe nor too recurrent in nature may be those that play a functional role.

Unfortunately, inconsistent and unreplicated findings from the sleep literature have not yet allowed consistent PSG profiles of either nightmare episodes or the typical sleep of nightmare sufferers to be claimed; reliable links to memory or emotion functions of sleep have thus not emerged. Similarly, a scarcity of neuropsychological findings provides few clues as to whether or how specific brain regions are implicated in nightmare formation or function.

Theories of nightmares fall along a spectrum; most theories consider the awakenings triggered by a nightmare to represent a temporary failure in regulating emotion, however repeated attempts and progressive resolution of nightmares may be necessary to down-regulate intense emotional experiences. In this regard, most theories consider dysphoric dreams and infrequent idiopathic nightmares to enable some type of emotion regulation function over time. However more frequent and recurrent nightmares are typically thought to reflect repeated attempts (and failures) in processes of emotion regulation. Many of these theories are a simple extension of general theories regarding emotional dreams, considering nightmares to represent failures in stress mastery, desomatization of affect, or fear memory extinction. Post-awakening theories also share the notion of emotion regulation; waking reactions to the nightmare—either spontaneous or therapist-assisted—feed back into the nightmare production system with

adaptive outcomes. The evolutionary theory of nightmares is distinct from these theories in claiming that nightmares enable development of threat perception and threat coping skills.

Despite this variety, however, many nightmare theories remain relatively vague as to the key mechanism, e.g., it is rare to find cellular or systems levels explanations. For those theories that propose more detailed explanations, supportive evidence is either still controversial or lacking altogether. Some of the theories are applicable only to certain types of nightmare experience, such as recurrent nightmares (Solms, 1997; Spoormaker, 2008), fear nightmares (Levin & Nielsen, 2007; Nielsen & Levin, 2007) or threat nightmares (Revonsuo, 2000), while others (Kellerman, 1987) deal with such a wide swath of emotions that predictions are not clear. In general, any theory of nightmares could benefit greatly from an increase in empirical and comparative investigation.

1.3.3 Do nightmares affect REM sleep-dependent memory integration?

A largely unexplored avenue of research in the nightmare population is the study of REM sleep-dependent emotional memory consolidation, particularly its role in the adaptive integration of emotional experiences within autobiographical memory networks. As described in section 1.1.5, the unique neurophysiological state of REM sleep allows activation of emotional memory traces within an environment of increased associative cortical connections, thus promoting emotional memory integration (Diekelmann & Born, 2010; Hu, Stylos-Allan, & Walker, 2006; Landmann et al., 2014; Payne, Chambers, & Kensinger, 2012; Payne, Stickgold, Swanberg, & Kensinger, 2008). The available literature points to two distinct hypotheses about whether nightmare sufferers would be expected to show an increase or a decrease in breadth of emotional semantic associations.

The majority of theories suggest that nightmares are dysfunctional instances of dreaming and may be related to inadequate regulation of emotion. Further, the most poignant symptom of the nightmare sufferer, the nightmare experience itself, is composed of rather repetitive and perseverative content, suggesting that nightmare psychopathology is characterized by restricted emotional semantic access. The nightmare's main theme and imagery seem to grow more potent and imposing over time, with an increase in emotional arousal, and a resistance to the associative fluidity that normally permeates dreams (Hartmann, 2011). This characterization of nightmares

as associationally restricted coincides with findings in the waking cognitive literature that show that positive emotion increases associative access while negative emotion restricts and slows it (Fredrickson, 2001; Selby, Anestis, & Joiner, 2008). Thus, the nightmare may reflect a temporary failure of REM processes to integrate a dysphoric emotional memory. Given this explanation, we would expect the presence of nightmares to correlate with reduced associational breadth and a blunting of REM sleep-dependent emotional priming.

An alternate possibility is that frequent nightmare sufferers are characterized by a broader than normal access to emotional semantic networks. This possibility is supported by findings that nightmare participants report more bizarreness in their daydreams (Carr & Nielsen, 2015; Walker, Conor, Hobson, & Stickgold, 2002). Nightmare sufferers are also characterized by "thin boundaries", a personality construct that includes creativity and artistic expression, both of which seem to draw more flexibly and frequently upon unusual associations (Hartmann, 2011). Together, such findings support an expectation that nightmare sufferers may demonstrate an increase in associational processing.

In sum, while research supports a role of REM sleep in the associative integration of emotional memory, any potential consequences of frequent nightmares on this process remain unknown. On the one hand, the nightmare experience seems to reflect associative restriction imposed by intense negative emotion; on the other hand, nightmare sufferers are frequently characterized as creative, artistic individuals. Assessment of their performance on the emotional Associational Breadth task developed for the first study may reveal whether nightmares confer a disturbance in emotional semantic associativity.

1.4 Approach and Objectives

1.4.1 Approach for Study 1

As reviewed earlier, the current state of research provides some consensus that REM sleep and REM dreaming may be functionally involved in a dynamic process of emotional memory integration and regulation, whereby the re-activation of recent emotional memory traces occurs within a REM sleep environment that enables broad associative spread from these traces to other relevant semantic and affective memories. This project was initially designed to

evaluate, in a sample of healthy control subjects, this proposed REM sleep function using a newly-designed associative semantic task in conjunction with a new morning nap protocol. These methods were complemented by the sampling and rating of mental imagery reports. We used morning naps to compare a NREM group, a REM group, and a wake control group, all probed at similar circadian times of day. Accordingly, two sets of dependent measures were developed for the study: 1) measures deriving from a REM-sleep sensitive Associational Breadth task; and 2) measures derived from an imagery attribute questionnaire.

1.4.1.1 Development of the Associational Breadth task

As elaborated in section 1.1.6, we developed a new task to assess the breadth of associational activation, specifically, the extent to which emotional and non-emotional cue-words lead to more remote associations in a semantic network. The task is based on empirically determined norms for the typicality of associations given by participants in response to common emotion and non-emotion cue-words (Altarriba, Bauer, & Benvenuto, 1999; Mednick, 1962). During administration of the task, participants are presented with these cue-words and respond with the first three words that come to mind as being meaningfully associated.

By comparing participants' responses with the empirically derived norms, we determine relative levels of associational breadth (i.e. the frequency of uncommon responses provided by the participants). To assess the effects of sleep/wake conditions on semantic consolidation of the cue-words, participants were instructed to memorize a sub-set of the emotion and non-emotion cue-words prior to sleep. The memorized words subsequently appeared as cue-words in the Associational Breadth task administered following sleep. Thus, we were able to determine whether memorization of stimuli prior to sleep led to changes in associational patterns after sleep, with the expectation that words studied prior to REM sleep would undergo extensive associational activation during REM sleep, leading to broader associational responses after the nap. Finally, the task allowed us to compare emotional to non-emotional stimuli, with the expectation that REM sleep would preferentially integrate emotional stimuli, leading to greater increases in emotional Associational Breadth after the nap.

1.4.1.2 Development of the mental imagery sampling procedure and measures

To systematically sample imagery content across sleep/wake states, we developed controlled imagery collection procedures for both waking daydreams and REM and NREM nap dreams (as detailed in section 1.2.5). For the daydream procedure, participants were asked to sit in a relaxed position on the bed for three minutes, keeping their eyes closed while they were free to think or daydream about anything. At the end of three minutes, an 80 dB 500-hz tone was sounded and they were instructed to immediately type in a report of whatever was going through their mind prior to the tone. Following this, participants completed a 10-item questionnaire about specific imagery attributes such as negative and positive emotion, and bizarreness (see below). The same procedure followed awakenings from sleep, when participants were signaled with the same 80 dB 500-Hz tone, and instructed to immediately type in a report of whatever was going through their mind prior to the beep. They then responded to the same 10-item questionnaire.

The 10-item questionnaire consisted of several attributes including clarity of dream recall, negative and positive emotions, sensory experience, and bizarreness, all of which are relevant for processes of REM sleep-dependent emotional memory integration (see section 1.3.1). All items were responded to on 1-9 Likert scales, with 1 being relatively little and 9 being relatively great levels of the given attribute in their imagery. The consistent use of procedures maximized the comparability of mental contents sampled from very different states.

1.4.1.3 Objectives and hypotheses for Study 1

Objectives of the first study were A) to compare the effects of waking, NREM, and REM sleep conditions on associativity to emotional stimuli, using a new Associational Breadth task (AB) and a morning nap study design; B) contrast attributes of mental imagery collected from waking, NREM, and REM sleep conditions, specifically, attributes of negative and positive emotionality, sensory vividness, and bizarreness.

Hypotheses: A) Associational Breadth

Hypotheses were that: A1) Associational Breadth would be highest after REM sleep awakenings, particularly for emotion cue-words, and would be positively correlated with time

elapsed in REM sleep; A2) Associational Breadth for both emotion and non-emotion cue-words would be higher after awakenings from REM than from NREM sleep or after an equivalent period of wakefulness.

Hypotheses: B) Mental Imagery

We expected that: B1) REM nap dreams would have higher self-rated scores of emotional intensity, sensory experience, and bizarreness than would NREM nap dreams; B2) compared with waking daydreams, REM nap dreams would have higher, and NREM nap dreams lower, scores of emotional intensity, sensory experience, and bizarreness.

1.4.2 Approach for Study 2

The project was extended to study the population of frequent nightmare sufferers in order to assess whether nightmares interfere with REM sleep-dependent emotional memory integration. Given the focus of nightmares and nightmare theories on negatively valenced emotion, the Associational Breadth task was divided into negative and positive associational stimuli. Also, the imagery questionnaire was modified in order to more closely assess attributes implicated in several of the nightmare function theories, including affective body sensations. Further, questionnaire assessments about individual differences in personality traits and potential comorbid symptoms, were added to complement the experimental findings. The continued inclusion of waking daydreams provided a means of understanding patterns of imagery that may permeate both waking and sleeping cognition. In sum, minor modifications to the study design were made to accommodate study of nightmare sufferers; these included: 1) isolation of positive and negative task stimuli; 2) increased sensitivity of imagery measures; 3) addition of questionnaires with nightmare relevance.

1.4.2.1 Modifications to the Associational Breadth task

As expected, in Study 1 participants who had had REM sleep during their nap gave less common word associations (scored relative to word associate norms; Altarriba, Bauer, & Benvenuto, 1999) than did participants who had had only NREM sleep during their nap or who had stayed awake. However, this priming effect was particularly strong for positive, compared to negative, cue-words. The positively valenced cue-words were thought to engender increased

spread of activation in REM sleep, similar to an effect observed in waking state priming studies. Given the potential differential effects of negative and positive stimuli on REM sleep-dependent memory processing, the emotional task was expanded to separate negative and positive cue-types. Thus, on each Association Breadth task administration, equal numbers of negative and positive cue-words were selected separately, each randomly without replacement, and presented to participants. Participants again were required to respond with the first three words that came to mind as being meaningfully associated to the presented cue-word, and these responses were scored in comparison to norms separately for positive and negative cue-words. Reaction times were recorded as the total time taken for participants to give three responses to each cue-word.

As in the first study, participants were instructed to memorize a word list prior to sleep, and these words subsequently appeared in a post-sleep Primed Associational Breadth task, which was compared to a NonPrimed Associational Breadth task in order to assess the effect of REM sleep on associational responses.

Further, in order to assess the durability of this effect, we added a one-week follow up.

1.4.2.2 Modifications to the imagery attribute questionnaire

The imagery attributes questionnaire used the same Likert scales as in the first study, with 1 being very little and 9 being extremely high on the designated attribute. However, additional, more nuanced, items were added to increase the sensitivity of the questionnaire, including items about the frequency of negative and positive emotions, and a "fear" item added to assess negativity, given the prevalence of fear in nightmares. Similarly, the bizarreness attribute was expanded to include several items, including bizarreness, discontinuity, unfamiliarity, and confusion. Further, the attribute of "sensory vividness" was modified to specifically assess body sensations, given that physiological arousal seems to be heightened in nightmare sufferers, and that body sensations can be considered a sensorial index of affect. Questions about task performance were removed from the imagery questionnaire.

Thus, the modified questionnaire consisted of 12 items. The first item assessed dream recall ("How clearly can you recall your experience?"). There were three items about negative imagery content ("What was the extent of negative emotion intensity/negative emotion frequency/fear in this experience?"), two items about positive imagery content ("What was the

extent of positive emotion intensity/positive emotion frequency in this experience?"), two items about body sensations ("What was the extent of positive/negative body sensations in this experience?") and four items about bizarre dream content ("To what extent was this experience unfamiliar/bizarre/discontinuous/confusing?"). Attribute ratings were calculated by averaging within categories to give a single score each for negative emotion, positive emotion, body sensation, and bizarre content, for daydream and dream conditions separately. High values on any of these average scores was taken to indicate intensification of the imagery for that particular attribute.

1.4.2.3 Additional questionnaires

A battery of questionnaires was administered to assess nightmare participant characteristics and potential comorbid symptoms; these included a questionnaires to assess the recall frequency of dreams, bad dreams (without awakening), and nightmares (with awakening), anxiety levels (State Trait Anxiety Inventory; Spielberger, Gorsuch, & Lushene, 1970), depression (Beck Depression Inventory; Beck, Steer, & Brown, 1996), nightmare distress (Nightmare Distress Questionnaire; Belicki, 1992), and alexithymia (Toronto Alexithymia Scale; Taylor, Bagby, & Parker, 2010).

1.4.2.4 Objectives and hypotheses for Study 2

To determine if the presence of frequent nightmares is associated with changes in emotional semantic access, we used a nap protocol and the modified emotional Associational Breadth task to assess semantic breadth for both negative and positive emotional words (Carr & Nielsen, 2015). Our objectives were to C) assess both baseline and REM sleep-dependent changes in emotional word associations among frequent nightmare sufferers (NM) and controls (CTL) and re-assess both tasks again at one week follow up. D) we also intended to compare waking daydream and REM dream reports of NM and CTL groups, using participants' ratings of affect, body sensation, and bizarreness in these reports.

Hypotheses: C) Associational Breadth

Given the prevalence of nightmare functional theories suggesting that nightmares interfere with REM sleep-dependent emotional memory processing, we expected NM subjects

to show lower Associational Breadth, particularly in response to negative cue-words, both without and with REM-sleep dependent priming i.e., C1) lower Associational Breadth scores, particularly for negative cue-words; C2) lower scores on the REM sleep-dependent Priming Effect, particularly for negative cue-words.

All effects were expected to be maintained for NM subjects after a 1-week delay.

Hypotheses: D) Mental Imagery

We predicted that NM sufferers would have more intensified waking daydreams and nap dreams, as indicated by D1) greater ratings of affect, elevated ratings of body sensations, and heightened bizarreness ratings in nap dreams, and D2) greater ratings of these attributes in waking daydreams.

2. Methods/Results

2.1 First Article

Morning REM sleep naps facilitate broad access to emotional semantic networks

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Michelle Carr: contributed to study design, subject recruitment, data collection, input, analyses, and writing

Tore Nielsen: contributed to study design, data analyses, and writing

Abstract

Study Objectives: Assess semantic priming to emotion and non-emotion cue-words using a novel measure of associational breadth for participants who either took REM or NREM naps or who remained awake; assess relation of priming to REM sleep consolidation and REM sleep inertia effects.

Design: The associational breadth task was applied in both a priming condition, where cue-words were signaled to be memorized prior to sleep (primed), and a non-priming condition, where cue-words were not memorized (non-primed). Cue-words were either emotional (positive, negative) or non-emotional. Participants were randomly assigned to either an awake (WAKE) or a sleep condition, which was subsequently split into NREM or REM groups depending on stage at awakening.

Setting: Hospital-based sleep laboratory,

Participants: Fifty-eight healthy participants (22 male) ages 18 to 35 (Mage=23.3 □4.08).

Measurements and Results: The REM group scored higher than the NREM or WAKE groups on primed, but not non-primed emotional cue-words; the effect was stronger for positive than for negative cue-words. However, REM time and percent correlated negatively with degree of emotional priming. Priming occurred for REM awakenings but not for NREM awakenings, even when the latter sleep episodes contained some REM sleep.

Conclusions: Associational breadth may be selectively consolidated during REM sleep for stimuli that have been tagged as important for future memory retrieval. That priming decreased with REM time and was higher only for REM sleep awakenings is consistent with two explanatory REM sleep processes: REM sleep consolidation serving emotional down-regulation and REM sleep inertia.

Keywords: memory, emotion, REM sleep, NREM sleep, associational processes, naps

Introduction

Different sleep stages have been linked to different forms of memory consolidation and learning. In general, NREM sleep has been associated with improved episodic and declarative memory whereas REM sleep has been associated with gains in semantic and emotional memory (Gujar, McDonald, Nishida, & Walker, 2011; Rauchs, Desgranges, Foret, & Eustache, 2005; Stickgold, 2005). Because episodic memory is the consolidation of explicit individual memories as they were experienced in time while semantic memory is the consolidation of generalized concepts and ideas, NREM sleep may function to consolidate the specific memories of personal experiences while REM sleep integrates these experiences into associative networks of more generalized knowledge and experience. Further, these purported NREM/REM differences in memory consolidation have parallels in the dreams sampled from either state: NREM dreams are emotionally and perceptually dry, drawing their content mainly from episodic memories, whereas REM dreams are more emotional, novel and bizarre, incorporating more pseudosensory qualities and combining recent and remote memories into an ongoing narrative (Antrobus, 1983; Nielsen, 2000).

Associational structure of semantic memory networks is broadened in REM sleep. A memory network can be conceptualized as a set of nodes which represent unique items in memory, connected by links that represent the semantic associations between nodes. Retrieval of knowledge from such a network relies on spreading activation, a process by which activation of one node spreads to surrounding nodes by virtue of the semantic closeness of their associational links (Anderson, 1983). The learning of associations between nodes is widely accepted to be a Hebbian process (Hebb, 2002), such that when two items in memory are simultaneously active, the association between them is strengthened and the likelihood increases that activation of one node will lead to activation of the other.

In sleep, the breadth of spreading activation may be modulated by changes in neurophysiology of the sleep state (Stickgold, Scott, Rittenhouse, & Hobson, 1999), for example, the activation of cortico-cortical connections (Walker & Stickgold, 2006) or altered regional modulation of brain neurotransmitters (Stickgold et al., 1999). During REM sleep, as opposed to during either NREM sleep or wake, there may be a broader spread of activation through the network such that individual memory traces activate more distant, uncommon or

atypical semantic associations but fail to activate more proximal, common or typical associations.

In the waking state, processes of spreading activation may be assessed by comparing participant performance with and without semantic priming (Collins & Loftus, 1975). Semantic priming refers to a change in one's ability to identify or produce an item as a result of specific prior encounters with a related item (Overson & Mandler, 1987; Tulving & Schacter, 1990). To illustrate, target words are processed more quickly or produced at a higher rate when preceded by (i.e., primed by) semantically related words than when preceded by unrelated words. Presumably, the priming words activate an underlying semantic network via spreading activation that improves access to the target words (Graf & Mandler, 1984; McDermott, 1997). Priming effects have been documented for both short (e.g., seconds, hours) and long (e.g., days, months) post-prime delays (Kvavilashvili & Mandler, 2004). They are, furthermore, facilitated by a multiplicity of interacting factors, including those that modulate state, such as mood (Ashby, Isen, & Turken, 1999; Topolinski & Deutsch, 2013), neurotransmitters (Foster et al., 2012), and sleep (Sio, Monaghan, & Ormerod, 2013).

NREM and REM sleep states may differentially inhibit or facilitate underlying semantic networks and these differences may be measurable during association tasks that are completed after awakening from these states. In fact, participants awakened from REM sleep and immediately administered an associative task display a priming effect for distantly related words (e.g., bread-health) whereas participants awakened from NREM sleep or tested during a wake condition display a priming effect for closely related words (e.g., bread-butter; Stickgold et al., 1999). These findings are thought to reflect qualitative differences in sleep inertia or the 'carry-over' of associational processes that were active during the two sleep stages, i.e., greater hyper-associativity and spread of activation during REM than during NREM sleep or wake (Stickgold et al., 1999). Similarly, associative processes as indexed by the quantity and originality of anagram solutions reflect such a carry-over effect from sleep into wakefulness: immediate post-REM testing produces an over 30% increase in the number of anagrams solved compared with post-NREM or wake testing (Walker, Liston, Hobson, & Stickgold, 2002). These findings, too, are interpreted to reflect greater fluidity and flexibility of thought in REM than in NREM sleep (Walker et al., 2002). We conceptualize these findings to indicate that access to semantic

networks is broader during REM sleep than it is at other times and that this altered access, when carried over into wakefulness, may modulate priming effects in the same way as other state-modulating factors such as mood. One possibility we examine in the present study is that the nature of the pre-awakening sleep episode (REM vs. NREM) modulates subsequent priming effects. Research on sleep inertia and carry-over effects are consistent with this conceptualization in that cognitive processes are impaired or altered for variable periods of time after awakening. These effects have physiological correlates, such as reduced transcallosal inhibition after REM awakenings (Bertini et al., 2004), which may influence some cognitive tasks for minutes but others for hours; the effects may also be enhanced following total or partial sleep deprivation (Hofer-Tinguely et al., 2005; Jewett et al., 1999; Tassi & Muzet, 2000).

Other types of experimental evidence bolster the notion that semantic associational networks are broadened during REM sleep and that these changes may be assessed by post-awakening testing. Semantic priming prior to sleep results in improved post-sleep performance on the Remote Associates Test for participants who undergo a REM sleep, but not a NREM sleep, nap (Cai, Mednick, Harrison, Kanady, & Mednick, 2009). In the latter study, prime words presented pre-sleep and then again post-sleep as part of the Remote Associates Test were more likely to result in solutions to task problems than were non-prime words. The pre-sleep exposure to prime words presumably led to the priming of "remote" semantic associations during the broad spreading activation of REM sleep, making them easier to access during the task problems post-sleep. Similarly, improvement in a second language, which is dependent on a broadening of semantic memory, correlates with an increase in %REM sleep (De Koninck, Lorrain, Christ, Proulx, & Coulombe, 1989). Such findings are in marked contrast to improvements in the learning of simple paired associates, whether semantically related (Goerke et al., 2012) or unrelated (Tucker & Fishbein, 2008), which are dependent upon the narrow network of associations that is presumably predominant during NREM sleep. In the present study, we introduce a new task designed to assess a semantic priming effect under the influence of either REM or NREM sleep inertia effects; we assess the extent to which primed and non-primed words influence an index of associational breadth in semantic networks as a function of prior sleep state.

In addition to evidence that the associational breadth of network access changes during sleep, a substantial literature demonstrates that REM sleep is critical for tasks involving memory for emotional stimuli and the regulation of emotional reactivity (Gujar et al., 2011; Hobson, Goldfrank, & Snyder, 1965; Kumar & Jha, 2012; Lara-Carrasco, Nielsen, Solomonova, Levrier, & Popova, 2009; Nishida, Pearsall, Buckner, & Walker, 2009; Rosales-Lagarde et al., 2012; van der Helm et al., 2011; Wagner, Gais, & Born, 2001). To cite but one example, retention of emotional versus neutral texts is enhanced when participants are allowed to sleep late, rather than early, in the sleep period, i.e., when sleep is much more likely to be REM, than NREM, in nature (Wagner et al., 2001). Although time in REM sleep has been found to correlate with improvements in emotional tasks (Nishida et al., 2009), one theory stipulates that REM sleep also involves a mechanism of emotional regulation that facilitates memory by a progressive suppression of emotional associations (Walker, 2009). We expected to see a positive correlation between time in REM sleep and extent of a priming effect in reaction to emotion (but not to non-emotion) cue-words. Further, because distinct brain networks govern the processing of emotional words—left inferior frontal cortex is more active for emotional words than for concrete words (Shallice & Cooper, 2013)—similarly distinct networks might be active during REM sleep. For these reasons, our new task investigates the influence of sleep on both emotional and non-emotional, concrete cue-words.

To summarize, REM sleep may promote a hyper-associative spread of activation in semantic networks, which may be important for the integration of recent memory traces with broad networks of associated memories. Such activation is revealed by tests that assess the semantic priming effects after awakenings from REM and NREM sleep or that assess changes in performance on associational tasks following pre-sleep priming. In the current study, a napping protocol is employed to assess associational breadth during REM and NREM sleep using emotional and non-emotional stimuli.

Objectives and hypotheses

Our objectives were to assess semantic priming to emotion and non-emotion cue-words using a novel measure of associational breadth (a presumed index of semantic spread of activation) for participants who either napped or remained awake and, for those who napped,

who underwent primarily REM or NREM sleep; and to assess the involvement in priming of REM sleep consolidation and REM sleep inertia effects. Our hypotheses were that 1) priming would be positively correlated with time elapsed in REM sleep (REM sleep consolidation), a correlation that would be higher for emotion than for non-emotion cue-words, and 2) priming for both emotion and non-emotion cue-words would be higher after awakenings from REM than from NREM sleep or after an equivalent period of wakefulness (REM sleep inertia).

Methods

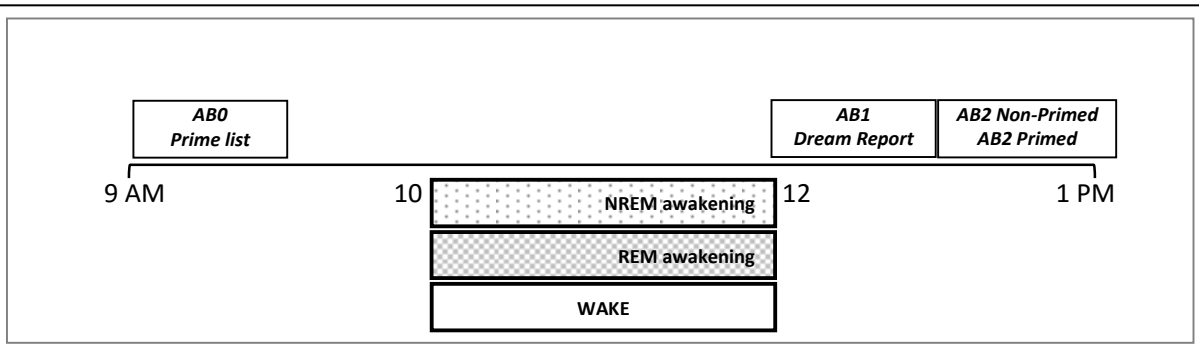
Participants

Fifty-eight healthy male (N=22) and female (N=36) participants between the ages of 18 and 35 (Mage=23.3□4.08) were recruited for a nap study using advertisements and posters. There were 25 participants in the NREM group (Mage=22.9±4.15, 9 men, 16 women), 22 in the REM group (Mage=24.1±4.13, 7 men, 15 women), and 10 in the WAKE group (Mage=22.6±4.12, 5 men, 5 women). There were no differences in ratios of males to females over the REM, NREM and WAKE groups ($\chi 2(2)=0.76$, $p=0.69$) and there were no age differences by sex for any of the 3 groups (all $p>0.16$). Potential participants were directed to call the laboratory for initial screening by phone. Exclusion criteria were self-reported sleep disorders, neurological, psychological, or other chronic illnesses, psychiatric disorders, addictions, inability to nap, use of certain medications, or other conditions that interfere with sleep. Participants were informed that they should not consume alcohol or caffeine for 24 hours before, as well as during, the experiment day. They completed an informed consent form that had been approved by the ethics committee of the Hôpital du Sacré-Coeur de Montréal.

Procedures

Participants arrived at 8 am, filled out the informed consent form, completed a questionnaire packet approximately 30 minutes in duration (not reported here) and then were prepared for the experimental task and sleep recordings.

Figure 1. Study Design.



Pre-sleep, participants completed the associational breadth task (AB0), consisting of 3 emotion and 3 non-emotion cue-words, and memorized another 6-item list of words that later served as primed cue-words. Post-nap, participants briefly summarized their dream report and repeated the associational breadth task with new emotion and non-emotion cue-words (AB1). Thirty minutes post-sleep they repeated the associational breadth task 2 more times (AB2). AB2 contained both new (non-primed: 3 emotion, 3 non-emotion) cue-words and familiar (primed: 3 emotion, 3 non-emotion) cue-words. NREM awakening: participants were awakened from NREM sleep; REM awakening: participants were awakened from REM sleep; WAKE: participants were kept awake but completed, on the same schedule, a waking imagery recall task (in lieu of a dream recall task) as well as all associational breadth tasks.

At 9 am participants were given task instructions and a practice trial before completing the pre-sleep associational breadth task (AB0) and memorizing the 6-item prime list (Figure 1). A sleep technician then attached an electrode montage for polysomnography, collected impedance measures, and performed biocalibration. At 10 am, participants were randomly assigned to either a group that was given a 2-hour window of opportunity for sleep or a group that was kept awake for the same period of time (WAKE group). Participants allowed to sleep were awakened approximately 80 minutes after sleep onset. A technician trained in sleep stage scoring determined stage of awakening and sleep stage measures. Participants who were awakened from NREM sleep were assigned to the NREM group and those who were awakened from REM sleep were assigned to the REM group. Some participants in the NREM group nonetheless had brief intervals of REM sleep before returning to NREM sleep. WAKE

participants were allowed to read or watch a movie and were constantly monitored to ensure they did not fall asleep.

Around 12 pm, sleep group participants were awakened with a non-stressful, 80 dB 500 Hz tone and asked to follow instructions on a computer screen that swiveled out from beside the bed. They were asked to report their dream and then to complete an associational breadth task with all new cue-words (AB1). WAKE participants were also signaled by a tone and asked to report on any ongoing waking mental imagery before completing the AB1 task. The AB1 task did not include a priming condition, the focus of the present study, so responses from this task along with the imagery reports are not further assessed. The electrode montage was then removed. Approximately 30 minutes post-awakening, participants completed two versions of the task, one which contained 6 new (non-primed: 3 emotion, 3 non-emotion) cue words (AB2-NP) and a second which contained 6 familiar (primed: 3 emotion, 3 non-emotion) cue-words (AB2-P). Participants were paid $40 for their participation.

Polysomnography: Participants slept (or stayed awake) in bedrooms with continuous audio-visual surveillance and a 2-way intercom. They were recorded with an electrode montage of 6 standard 10-20 EEG channels (F3, F4, C3, C4, O1, O2) referenced to A1, and 4 EOG (vertical and horizontal channels) and 1 bipolar EMG channel (chin). Biosignals were recorded using Grass M12 and Grass M15 Neurodata Acquisition Systems (-6dB filters with cut-offs at 0.30 and 100 Hz) and archived under the control of Harmonie 5.4 software (Stellate Systems, Montreal, Canada). PSG tracings were scored according to current AASM standards (Berry et al., 2012) by an experienced PSG technician and standard sleep variables (REM min, %REM, NREM min, %NREM, TST) were calculated using in-house software.

Task development and administration: We developed a new task to assess levels of, and changes in, breadth of associational activation, i.e., the extent to which a cue-word leads to more remote associations in a semantic network. The task is based on theories of associative processing described earlier and draws upon empirically determined norms for the typicality of associations that are given by participants in response to emotion and non-emotion (or concrete) cue-words (Altarriba, Bauer, & Benvenuto, 1999; Mednick, 1962). The latter norms contain 98 emotion and 100 non-emotion cue-words, imageability and concreteness ratings for each, and the words that were most frequently associated to each cue-word (Altarriba et al., 1999). For

this study, a total of 18 emotion and 18 non-emotion cue-words were chosen from these norms to be matched on ratings of imageability (>6/7 for non-emotion words, >4/7 for emotion words) and number of word-associates (exactly 3 word associates given by >70% of participants); cue-words differed on concreteness ratings (>6/7 for non-emotion words, <4/7 for emotion words).

On each administration of the task (AB0, AB1, AB2-NP, and AB2-P), 3 emotion and 3 non-emotion cue-words, each randomly selected without replacement from the sets of 18 emotion and 18 non-emotion cue-words, were presented. For each trial, one cue-word was presented and participants were required to respond with the first three words that came to mind as being meaningfully associated. A maximum of 30 seconds was allowed to type out the 3 words; a countdown clock on the screen displayed the time remaining for each cue-word. The presentation software ("Inquisit 4.0.0.1 [Computer software]," 2012) recorded all words typed by participants. The next trial was administered 500 ms after the end of the previous for a total of 6 trials and a maximum task time of 3 minutes.

The norms (Altarriba et al., 1999) were used to score associational breadth of responses to each cue-word; any word associate not in the norms was considered to be uncommon and scored as 1, otherwise as 0. Associational breadth scores for emotion and non-emotion cue-words on a single task administration therefore varied between 0 (all common associates) and 9 (all uncommon associates). For some analyses, associational breadth scores were assessed separately for positive and negative valence emotion cue-words; because emotion cue-words were randomly selected for presentation, proportions of positive and negative valence cue-words were not equally represented in all cells of the experimental design.

Priming Task: Following administration of the pre-nap AB0 task, participants were instructed to memorize a list of 3 emotion and 3 non-emotion cue-words, each randomly selected without replacement from the sets of 18 emotion and 18 non-emotion cue-words described above. These 6 words were presented for memorization in randomized order, 4 sec/word, on each of three sequential presentations. After the sleep (or wake) interval, all 6 memorized words were subsequently presented as primed cue-words in administration of the post-nap AB2-P task, whereas new cue-words were presented in the AB2-NP task. Participants were never actually tested on their recall of these words, but their earlier presentation as to-be-remembered stimuli endowed them with the properties of semantic primes that were either emotional or non-

emotional in nature. The primary dependent measure, relative priming, was calculated by subtracting non-primed AB2-NP from primed AB2-P scores for emotion and non-emotion cue-words separately. This measure controls for within-subject factors not specific to change-from-baseline effects, e.g., multiple task administrations, and other state- and context-related confounds. Positive scores indicated that primed cue-words produced more uncommon associates than did non-primed cue-words; negative scores indicated the opposite.

Statistical Analyses

The principal set of analyses assessed priming and the implication of a possible REM sleep consolidation effect. We conducted a 2x3 ANOVA with cue-word type (emotion, non-emotion) as a repeated measures factor, sleep state (REM, NREM, WAKE) as a between groups factor, and extent of relative priming as the dependent measure. One-way ANOVAs and post-hoc t-tests then isolated the interaction effect and compared positive, negative and non-emotion priming cue-words. Spearman correlations between positive, negative and non-emotion cue-word priming and min/% time in sleep stage (REM and N3) tested a possible REM sleep consolidation effect. To assess REM sleep inertia effects, sleep groups were split into subgroups containing different compositions of REM and NREM sleep (see later). Relative priming scores for 5 awakening subgroups (WAKE, N, N-R, N-R-N, N-R-N-R) were compared using one-way ANOVAs and post-hoc t-tests comparing specifically N-R-N vs. N-R and N-R-N-R subgroups.

Results

Sleep architecture

The sleep recording for 1 participant in the REM group was removed from these analyses because of technical difficulties. Sleep measures for the REM and NREM sleep groups are reported in Table 1; groups differed in %REM sleep ($t(45)=-2.60$, $p=0.012$, 2-tailed) and marginally in REM minutes ($t(45)=-1.75$, $p=0.089$). They also differed in %NREM sleep ($t(45)=-2.60$, $p=0.012$), as this measure is inversely proportional with %REM, but they did not differ in TST or NREM sleep minutes.

Table 1. Sleep stage measures for naps of the REM and NREM groups.

TST=Total Sleep Time; NR1=NREM stage 1; NR2=NREM stage 2; NR3=NREM stage 3.

	NREM	**REM**		
N	25	22		
sex ratio (m:f)	9:16	7:15		
	Mean±SD	**Mean±SD**	**p**	
Nap onset time (hh:mm)	11:23±0:53	11:07±0:47	.302	
Nap offset time (hh:mm)	13:00±0:55	12:43±0:44	.266	
TST (min)	73.4±22.45	74.7±17.86	.829	
REM (min)	10.5±13.84	16.0±7.50	*.089*	
NREM (min)	62.9±16.28	58.6±15.47	.357	
NR1 (min)	14.5±7.50	13.0±6.13	.466	
NR2 (min)	34.5±15.00	31.0±9.85	.359	
NR3 (min)	14.0±14.68	14.6±12.50	.875	
REM (%)	**12.3±14.63**	**21.6±8.57**	**.012**	*
NREM (%)	**87.7±14.63**	**78.4±8.57**	**.012**	*
NR1 (%)	22.1±14.13	18.0±8.61	.251	
NR2 (%)	46.7±14.00	41.9±10.29	.187	
NR3 (%)	18.9±19.54	18.5±15.09	.940	
Sleep latency (min)	8.0±6.09	8.3±5.91	.876	
REM latency (min)	34.3±25.85	45.3±35.82	.311	
NR1 latency (min)	7.8±6.11	7.5±5.15	.857	
NR2 latency (min)	16.8±6.46	15.1±8.33	.451	
NR3 latency (min)	35.8±14.72	31.3±15.44	.364	

Task Performance as a function of sleep stage

Mean associational breadth scores and standard deviations for each task session for each of the 3 groups are reported in Table 2. Groups did not differ on Pre-nap AB0 scores for either emotion or non-emotion cue-words (all $p>0.65$).

Table 2. Mean (±SD) Associational Breadth (AB) scores for all conditions and groups.

AB0=Pre-nap; AB1=immediate post-nap; AB2-NP=30-min post-nap, non-primed cue-words; AB2-P=30-min post-nap, primed cue-words.

	Emotion Cue-Words				Non-emotion Cue-Words			
Group (N)	**AB0**	**AB1**	**AB2-NP**	**AB2-P**	**AB0**	**AB1**	**AB2-NP**	**AB2-P**
WAKE (10)	0.64±0.164	0.70±0.149	0.71±0.119	0.66±0.206	0.66±0.152	0.71±0.141	0.68±0.143	0.69±0.180
NREM (25)	0.67±0.143	0.66±0.155	0.64±0.190	0.60±0.195	0.64±0.174	0.62±0.133	0.63±0.159	0.63±0.181
REM (23)	0.68±0.183	0.62±0.224	0.62±0.181	0.79±0.152	0.65±0.151	0.73±0.195	0.71±0.153	0.73±0.180

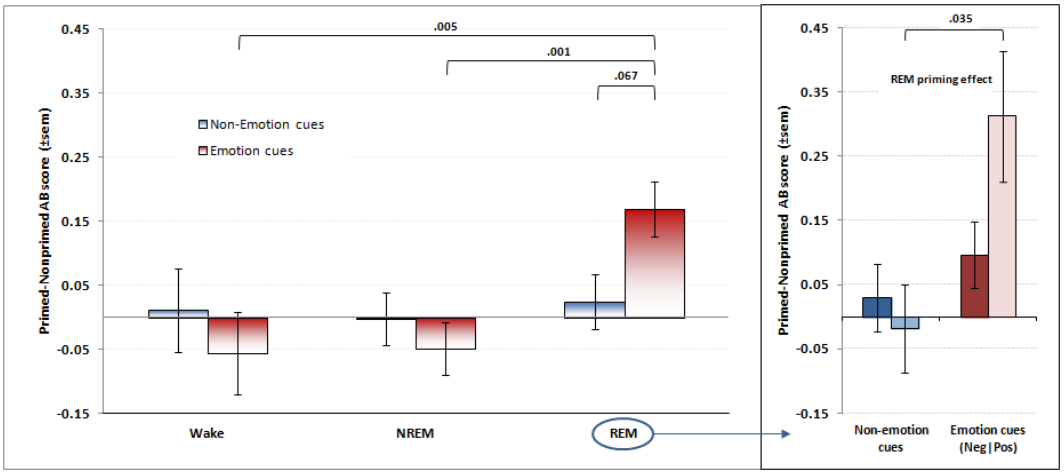
Priming Effect

The 2x3 ANOVA on the relative priming measure produced a main effect for Group ($F(2,55)=5.02$, $p=.010$), no main effect for CueType ($F(1,55)=0.06$, $p=.805$), and a nearly-significant Group x CueType interaction ($F(2,55)=3.07$, $p=.054$). This pattern indicated that the 3 groups differed on the emotion but not the non-emotion cue-words. Specifically, as shown in Figure 2, left panel, emotion cue-words produced a priming effect that was higher for the REM group (M=.169±.204) than for either the WAKE (M=-.056±.176; $t(55)=2.90$, $p=.005$) or NREM (M=-.049±.215; $t(55)=3.68$, $p=.001$) groups. Priming for the REM emotion cue-word condition was also marginally greater than for the REM non-emotion (M=.024±.255) condition ($t(22)=1.93$, $p=.067$).

Post-hoc analyses of cue-word differences by emotional valence revealed a significant oneway ANOVA on priming for positive cue-words ($F(2,31)=6.86$, $p=.004$) such that the REM group (M=.313±.352) differed from the NREM group (M=-.150±.363; $t(23)=3.23$, $p=.004$, not shown) and from the WAKE group (M=-.048±.081; $t(17)=2.64$, $p=.017$) while the NREM and WAKE groups did not differ ($t(18)=0.72$, $p=.479$). A similar oneway ANOVA on priming for negative cue-words was not significant ($F(2,47)=1.88$, $p=.165$) with no differences between the REM (M=.096±.227) and NREM (M=-.008±.258) groups ($t(37)=1.35$, $p=.187$, not shown), the REM and WAKE (M=-.092±.294) groups ($t(26)=1.87$, $p=.072$), or the NREM and WAKE groups ($t(27)=-0.78$, $p=.443$). Within the REM condition alone, post-hoc tests showed that priming for positive (M=.313±.352) and non-emotion (M=-.018□.236) cue-words differed ($t(11)=2.40$, $p=.035$, Figure 2, right panel) but not priming for negative (M=.096±.227) and non-

emotion (M=.029±.231) cue-words (t(18)=0.81, p=.428; Figure 2, right panel). No other differences between or within conditions were found.

Figure 2. Priming Effect for Wake, NREM, and REM groups.



Left panel: relative priming, calculated as primed minus non-primed associational breadth scores, was elevated only for emotion cue-words and only for the REM sleep nap group. Right panel: detail of REM priming effect: post-hoc tests show that only cue-words with a positive emotional valence produced a priming effect at p<.05; two bars are shown for non-emotion cues due to slightly different size groups of participants receiving at least 1 negative (n=19) and at least 1 positive (n=12) cue-word. P-values are shown for pertinent within and between groups contrasts.

In sum, relative priming comparisons revealed substantial evidence for a REM sleep emotional priming effect that was more apparent for positive than for negative emotion cue-words.

Correlational analyses

As shown in Table 3 and Figure 3, Spearman correlations between relative priming measures (positive, negative, non-emotion) and measures of time and % in sleep stage revealed that, for REM awakenings, priming for positive cue-words correlated negatively with REM min (r(12)=-.649, p=.022) and REM% (r(12)=-.757, p=.004) and positively, albeit non-significantly, with NR3 min (r(12)=.413, p=.182) and NR3% (r(12)=.420, p=.174). Priming for negative cue-words showed an opposite pattern of correlations: non-significantly positive with REM min and

REM% (both p>.28) and negative with NR3 min (p=.10) and NR3% (p=.05). For NREM awakenings alone, only non-significant or marginal correlations between priming and times in sleep stage were found. Although only one of the previous correlations would survive a familywise error correction for multiple comparisons (.05/7 sleep measures per CueType family = .007), Fisher r-to-z analyses nonetheless indicate that REM x positive cue-word correlations differ substantially from those for REM x non-emotional cue-words, e.g., REM minutes (z=-2.81, p=.005) and REM % (z=-3.50, p=.0005; see Table 3).

Table 3. Spearman correlations between sleep stage and relative priming scores for positive, negative, and non-emotion cue-words.

Zero-order correlation p-values at <.05 are highlighted in bold.

	REM awakenings			NREM awakenings		
	negative	positive	non-emotion	negative	positive	non-emotion
REM (min)	0.203[a]	**-0.649**[a]	0.348[a]	-0.430	-0.136	-0.200
p	*0.405*	***0.022***	*0.112*	*0.058*	*0.658*	*0.339*
NR2 (min)	0.207	-0.160	-0.074	-0.172	0.446	-0.377
p	*0.394*	*0.620*	*0.743*	*0.469*	*0.127*	*0.063*
NR3 (min)	-0.386[b]	0.413[b]	-0.041	0.052	0.229	0.022
p	*0.103*	*0.182*	*0.856*	*0.828*	*0.452*	*0.915*
TST (min)	0.077	-0.185	-0.037	-0.376	0.070	-0.232
p	*0.753*	*0.564*	*0.870*	*0.103*	*0.821*	*0.264*
REM (%)	0.256[c]	**-0.757**[c]	0.404[c]	-0.368	-0.233	-0.167
p	*0.289*	***0.004***	*0.062*	*0.110*	*0.444*	*0.425*
NR2 (%)	0.333	-0.105	-0.174	0.050	0.351	-0.180
p	*0.164*	*0.745*	*0.440*	*0.834*	*0.240*	*0.388*
NR3 (%)	**-0.456**[d]	0.420[d]	-0.072	0.050	0.229	0.087
p	***0.050***	*0.174*	*0.749*	*0.835*	*0.452*	*0.679*

Between cue-type comparisons (Fisher r-to-z): [a]REM min: positive cue-word correlations differ from negative (z=-2.35, p=.019) and non-emotional (z=-2.81, p=.005); [b]NR3 min: positive cue-word correlations differ from negative (z=2.03, p=.042); [c]REM%: positive cue-word correlations differ from negative (z=-3.00, p=.003) and non-emotional (z=-3.50, p=.0005) cue-words; [d]NR3%: positive cue-word correlations differ from negative (z=2.26, p=.024).

Figure 3. Spearman correlations between relative priming scores and sleep stage.

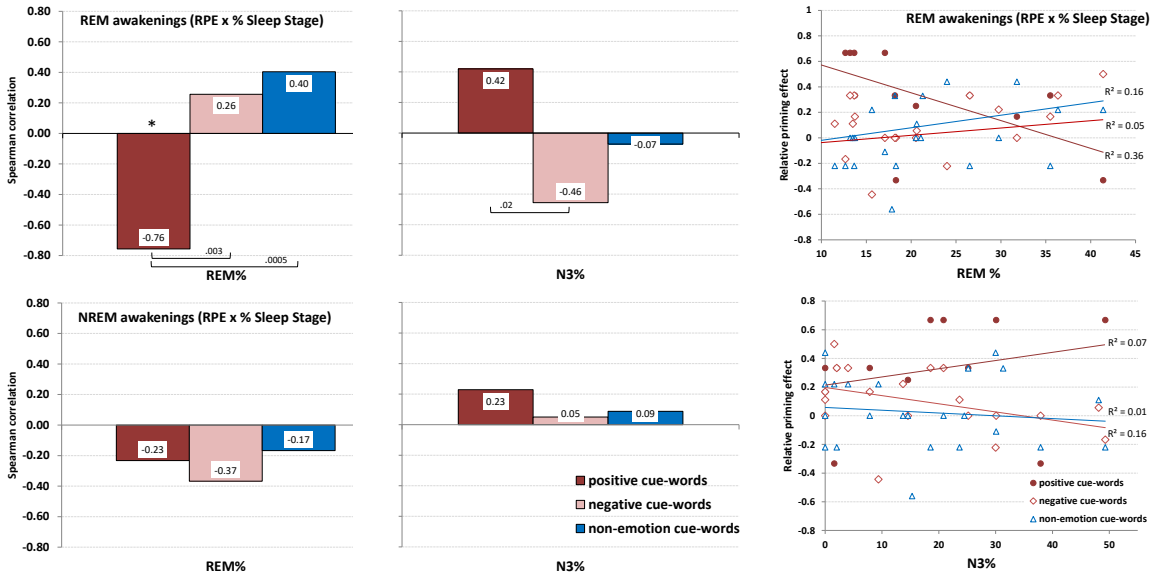


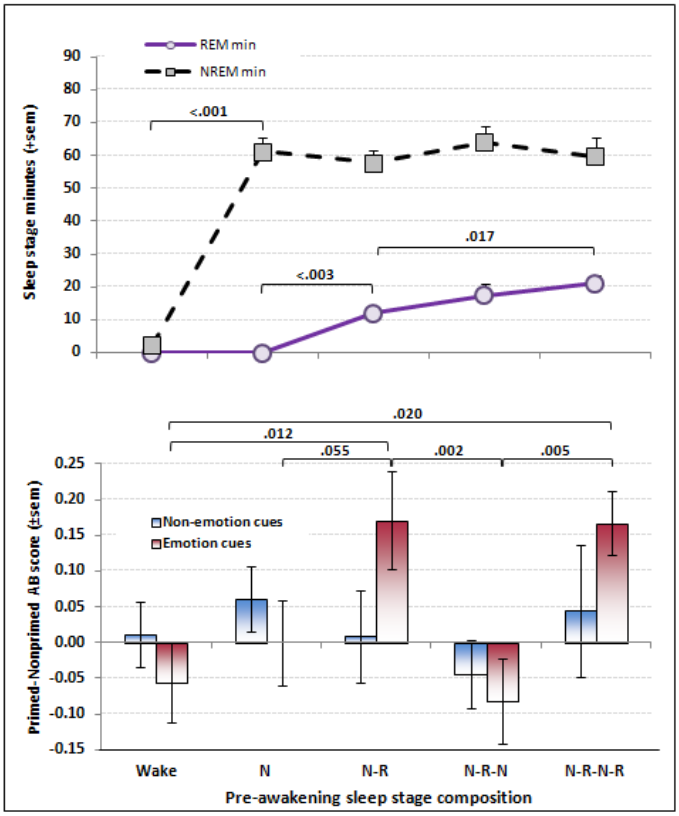
Figure 3. Spearman correlations between relative priming scores and time in sleep stage (REM min, NR3 min) for REM (upper bar graphs) and NREM (lower bar graphs) awakenings. Scattergrams shown for REM awakenings (right panel). *p<.02, Correlations with positive cue-words differed from those with negative and non-emotion cue-words for REM awakenings (p-values for Fisher r-to-z comparisons shown with brackets).

Sleep stage inertia effects

To test whether the REM priming effect was facilitated by REM stage awakenings (REM sleep inertia), NREM and REM awakening groups were divided into the following 4 subgroups: 'N' (single NREM episode); 'N-R' (episode consisting of NREM followed by REM); 'N-R-N' (sequence of NREM, REM, NREM) and 'N-R-N-R' (sequence of NREM, REM, NREM, REM). Subgroup sizes were n=10, 13, 15 and 10 respectively. REM awakenings thus occurred for N-R and N-R-N-R while NREM awakenings occurred for N and N-R-N. As shown in Figure 4, upper panel, all 4 groups contained similar NREM sleep minutes and N-R-N did not differ from either N-R or N-R-N-R in REM sleep minutes (although the latter two differed). Oneway ANOVAs and t-tests specifically contrasting N-R-N with N-R and N-R-N-R groups revealed that means for emotion cue-words differed significantly ($F(4,53)=3.47$, $p=.021$) whereas those for non-emotion cue-words did not ($F(4,53)=0.48$, $p=.751$). As shown in Figure 4, lower panel,

priming for emotion cue-words did not differ for N-R and N-R-N-R groups and the latter were both greater than those for N-R-N (p=.002 and .005 respectively). Secondary analyses revealed that: the former 2 groups differed marginally from group N (p=.055 and .077 respectively); N and N-R-N did not differ from each other; N-R and N-R-N-R were greater than WAKE (p=.012 and .020); and N and N-R-N were not different from WAKE. There were no differences among groups for non-emotion cue-words (all p>.218).

Figure 4. Relative priming for subgroups with differing pre-awakening stage.



Upper panel: subgroup of NREM awakenings with some prior REM (N-R-N) did not differ from subgroups of REM awakenings (N-R and N-R-N-R) in total minutes of NREM (p=.309 and .512 respectively) or REM sleep (p=.119 and .331). Lower panel: Priming is elevated for emotion cue-words only after awakenings from REM sleep even though N-R-N contains substantial REM sleep, suggesting a selective carry-over effect on priming for REM groups. There was no carry-over effect for non-emotion cue-words. N=NREM; N-R=NREM+REM; N-R-N=NREM+REM+NREM; N-R-N-R=NREM+REM+NREM+REM.

To summarize these findings for WAKE, REM and NREM group analyses, a priming effect for emotional cue-words was elevated for participants awakened from REM but not NREM sleep, whether or not the preceding NREM sleep possessed any REM sleep.

Discussion

The associational task developed for this study proved successful in demonstrating a selective association between REM sleep and a priming effect for emotional cue-words—especially for cue-words of a positive emotional valence. As predicted, when participants were awakened from REM sleep and asked to provide word associations to emotion cue-words that had been primed prior to sleep, the semantic atypicality of these words increased relative to when associations were to cue-words that were either not previously primed or not emotional. This pattern of differences was not seen for participants who had been awakened from NREM sleep, nor was it clearly characteristic of participants who had not slept at all.

These results extend findings demonstrating that REM sleep is associated in a general sense with performance improvements on emotional memory tasks (Gujar et al., 2011; Kumar & Jha, 2012; Lara-Carrasco et al., 2009; Nishida et al., 2009; Rosales-Lagarde et al., 2012; van der Helm et al., 2011; Wagner et al., 2001). This includes improvement in discrimination accuracy for facial emotions (Gujar et al., 2011), recall of emotional texts (Wagner et al., 2001), recognition of emotional pictures (Groch, Wilhelm, Diekelmann, & Born, 2013) and consolidation of complex negative scenes (Payne, Chambers, & Kensinger, 2012). And although much of this previous research has examined REM sleep's implication in tasks involving negative emotions, an increasing number of studies (Chambers & Payne, 2013; Gujar et al., 2011) indicate that positive emotional stimuli are also REM sleep-dependent. Our post-hoc finding of a priming effect selective for positive cue-words is consistent with the latter studies but clearly requires further replication.

Beyond supporting a role for REM sleep in emotional memory, our results are also consistent with sleep studies that have employed specific types of semantic priming tasks. First, our results are fully consistent with the prior demonstration (Cai et al., 2009) that performance on a primed Remote Associates Test (RAT) is enhanced when participants have intervening REM sleep but not when they have NREM sleep or quiet rest. The solving of RAT word triads

(e.g., RABBIT CLOUD MILK; solution: WHITE) has been described as due to spreading activation through the weak (remote) links of semantic networks for the cue-word triads (Topolinski & Strack, 2009). When one of the cue-words is primed (i.e., presented in another context) prior to sleep its semantic network is presumably activated and consolidated during subsequent REM sleep. And, as we suggest for the priming effect in our own results (see later), the information in this network is therefore more readily accessible later during the RAT administration. Previous work on priming effects may help explain why in the present study the REM-facilitated priming effect was observed primarily for emotionally positive cue-words. Induction of a positive mood is now widely known to facilitate spread of activation and, thus, priming effects (Topolinski & Deutsch, 2013). Positive mood also improves success with RAT solutions (Corson, 2002; Haänze & Hesse, 1993; Isen, Daubman, & Nowicki, 1987) and increases the unusualness and diversity of word associations (Isen, Johnson, Mertz, & Robinson, 1985).

Second, the present results converge with the finding that there occurs less loss of priming to word-stem stimuli after an interval of late night sleep (rich in REM) than there is after an interval of early night sleep (rich in NREM; Plihal & Born, 1999). Third, the results are consistent with those of a study that showed more response errors in a masked visuomotor priming task after late night than after early night sleep (Verleger, Schuknecht, Jaśkowski, & Wagner, 2008). Errors in that study were due to increased priming of masked visuomotor stimuli and thus the increase in errors following more time spent in REM suggests successful priming. Finally, our findings converge with those from a study in which enhanced positive repetition priming in a face identification task was found after late night, REM rich sleep (Wagner, Hallschmid, Verleger, & Born, 2003).

Two REM sleep mechanisms for priming facilitation? While a REM sleep-related priming effect is clear in our findings, evidence points to two mechanisms that may underlie this effect: REM sleep mediated consolidation and REM sleep inertia (or carry-over). REM sleep consolidation is suggested primarily by a significant correlation between magnitude of the priming effect for positive cue-words and minutes and percent of REM sleep; it suggests that priming stimuli were further processed during REM sleep and may thus have influenced the post-sleep retest. In contrast, a REM sleep inertia effect is suggested primarily by the specific

association of priming with REM sleep awakenings (N-R, N-R-N-R subgroups) but not with NREM awakenings that nonetheless contained prior REM sleep (N-R-N subgroup). Stage of awakening (REM) was thus independent of prior REM time, a result consistent with our suggestion that both REM consolidation and REM sleep inertia together produced the REM-related priming apparent in our results.

REM sleep consolidation. Although other explanations are possible, we speculate that presentation of the word list for memorization prior to sleep led it to be 'tagged' for memory storage (Redondo & Morris, 2011), and thus for its semantic networks to be selectively reactivated during subsequent REM sleep. The hyper-associative nature of REM sleep presumably facilitated—and consolidated—a broader than normal spread of activation through these networks. Because REM sleep is particularly sensitive to emotional material (Walker & van Der Helm, 2009), activation of the networks for primed emotion words were likely favored over those for primed non-emotion words. When participants were awakened from REM (but not from NREM) sleep and the primed emotional words were subsequently presented as cue-words, the now consolidated broad networks linked to these words were presumably more easily accessed, leading to the production of more distantly related word associates.

While our principal findings strongly support a role for REM sleep in emotional priming, the unexpected negative correlations between the magnitude of positive cue-word priming and time and percent REM sleep requires further consideration. The finding is strikingly similar to a previously reported, unexpected result (Stickgold et al., 1999): that amount of priming of distantly-related word pairs (e.g., bread-health) elicited after REM sleep awakenings decreased, rather than increased, as these awakenings took place progressively later in the night, i.e., as REM time increased. As in our study, these authors found that priming diminished as REM periods became longer and physiologically more intense. We propose an explanation that is consistent with the possibility that the associational REM sleep activity contributing to priming is also implicated in a functional mechanism of emotional regulation at this time.

Specifically, an emotion regulation function for REM sleep has been proposed by several authors (Cartwright, Agargun, Kirkby, & Friedman, 2006; Greenberg, Pillard, & Pearlman, 1972; Lara-Carrasco et al., 2009; Walker & van Der Helm, 2009). Among these, the SFSR (sleep to forget and sleep to remember) model of emotional memory processing (Walker & van Der

Helm, 2009) is a particularly apt fit to the present findings. The SFSR model stipulates that connectivity of emotional memory elements depends upon the progressive diminution—within and across REM periods—of the emotional charge that was associated with those elements during encoding. Accordingly, in the present study emotional words that were presented for memorization prior to sleep may have been queued for a process of emotional down-regulation during the next available REM sleep episode. As that REM episode unfolded, the prime words may have become progressively more consolidated in memory yet progressively denuded of their emotional charge, resulting in REM-associated priming that was less marked for longer REM periods. Thus, although REM sleep mechanisms were necessary for emergence of the priming effect, more time elapsed in REM sleep may have successfully decreased the emotional charge of the primed cue-words and thus diminished the intensity of the subsequent priming effect.

The combination of REM-dependence and a negative correlation between priming and REM time is not unlike work demonstrating sleep stage association with a learning effect that is nonetheless independent of time-in-stage (Schönauer, Geisler, & Gais, 2013; Tucker & Fishbein, 2008). In one such study, declarative memory performance was found to improve after a 60-minute NREM sleep nap even though performance was not correlated with time in NREM (Lahl, Wispel, Willigens, & Pietrowsky, 2008). A follow-up study found that naps as short as 6 minutes nevertheless conferred memory improvement relative to a waking state control. Thus, it may be the appearance of the sleep stage, rather than the amount of time spent in that stage, that is critical for memory gains. It should be noted that the priming effect we observed was also positively, albeit not significantly, correlated with minutes of N3 sleep, so we cannot exclude the possibility that the hypothesized consolidation process was linked to NREM, rather than REM, sleep processes. NREM sleep is known to facilitate consolidation of many types of stimuli, including emotional stimuli (Cairney, Durrant, Hulleman, & Lewis, 2014).

REM sleep inertia. That the priming effect for emotion cue-words was associated selectively with REM (but not NREM) sleep awakenings in our results replicates in a general sense the findings of many previous studies that have demonstrated sleep inertia and carry-over effects of various durations (Santhi et al., 2013; Tassi & Muzet, 2000). While findings are inconsistent on the exact duration of sleep inertia—estimates range from minutes to hours

(Hofer-Tinguely et al., 2005; Jewett et al., 1999; Tassi & Muzet, 2000) —inconsistencies are likely a function of task type, outcome measure, experimental manipulation, quality of prior sleep, and other confounding factors. The appearance of our priming effect at approximately 30 minutes post-awakening is thus well within expectations, but only for some types of cognitive tasks. Lower level processes, such as attention, are more severely affected by sleep inertia (and thus recover more slowly) than are higher level processes such as working memory (Santhi et al., 2013) and, presumably, spread of activation in semantic networks is a lower level cognitive process whose automaticity is prerequisite to basic language comprehension and production.

Our findings also replicate the more specific finding that REM sleep inertia affects cognitive processes differently than does NREM sleep inertia (Bertini, Violani, Zoccolotti, Antonelli, & Di Stefano, 1984; Stickgold et al., 1999), e.g., increasing priming of remote semantic associates after only REM sleep awakenings (Stickgold et al., 1999). In the latter study, a target word (e.g., 'wrong') that was only weakly related to a prior prime word ('thief') was more quickly recognized as a word a few minutes after REM than after NREM sleep awakenings; in contrast, priming of a strongly-related target word (e.g., 'hot-cold') was not facilitated. Weakly-related word pairs correspond closely to the atypical responses on the associational breadth task in our results, as these consist of words that are not strongly related to cue-words in a normative sample (Altarriba et al., 1999). In both studies, awakenings from REM sleep selectively facilitated access to these more weakly related semantic associations. And our results go further in separating stage of awakening from prior time-in-stage in that our NREM awakening participants in the N-R-N subgroup showed no increase in priming even though their time in REM sleep did not differ from that of either of the REM awakening groups (N-R, N-R-N-R). Further, whereas Stickgold and colleagues demonstrated increased priming in response to non-emotion cue-words, we found that emotion, but not non-emotion, cue-words facilitated priming. It is thus possible that REM sleep inertia for non-emotional priming dissipates well before 30 minutes post-awakening whereas inertia for emotional priming persists for 30 minutes or longer. The relative durations of REM sleep inertia effects on different types of cognitive tasks remains relatively unknown; much more research is clearly warranted.

It is noteworthy that sleep inertia may be modulated by circadian rhythmicity (Scheer, Shea, Hilton, & Shea, 2008) and, because our naps occurred in late morning, which is earlier

than most nap studies reported in the literature and close to the zenith of REM sleep propensity, it is likely that REM sleep inertia was at a maximum for our participants. This, too, requires further study. Finally, it should be noted that we administered the unprimed associational breadth task on two other occasions before the priming administration, once pre-sleep and once immediately post-awakening. It is therefore possible that a participant's later performance on the task, the unprimed task in particular, was influenced by factors such as learning. For example, our additional post-awakening administrations may have facilitated dissipation of sleep inertia for the unprimed task selectively, thus enhancing the apparent difference between later primed and unprimed scores. However, some considerations mitigate against such an interpretation. First, multiple administrations of a task are common in sleep inertia studies (Santhi et al., 2013) and generally accepted as a valid procedure for assessing dissipation of sleep inertia. Some investigators reduce learning effects by giving multiple 'practice' sessions of a task prior to testing, but this could also induce unwanted priming effects in semantic priming protocols such as ours. Second, each of our unprimed task administrations used different cue-words; thus, the likelihood of learning, habituation or even secondary priming of the unprimed task was reduced.

In sum, we suggest that our findings reflect the operation of two REM sleep-related mechanisms that facilitate an emotional priming effect: a consolidation mechanism related to emotional down-regulation and a sleep inertia effect that persists until the time of testing. This two-factor explanation closely parallels a similar explanation by Kvavilashvili and Mandler (2004) of how autobiographical memories appear involuntarily during wakefulness: they are produced by 'the cumulative action of long term residual activation of a prime per se and relatively short term (associative) spreading of activation in response to one's current situation' (see p.82 of Kvavilashvili & Mandler, 2004).

A possible role for dreaming? Several of the previously-cited authors consider dreaming to be implicated in the observed sleep-related priming effects. For example, Stickgold et al. (1999) concluded that their findings help explain the 'bizarre and hyper-associative nature of REM-sleep dreaming (p. 188)'. Similarly, Mazzetti et al. (2006), suggest that the integrative processes of dreaming are implicated in the altered spread of semantic activation reflected by their priming effect. While we also postulate that our findings reflect the hyper-associativity of

semantic networks during REM sleep, and although additional analyses of our detailed mentation samples may yet provide support for the claim that dreaming participates in this hyper-associativity, nothing reported in the present results directly supports this more general claim. The present findings do suggest, however, that the affective content of dreams—positive affect especially—may be associated with the emotional priming effect. For example, positive dream affect may either facilitate the consolidation of emotional primes in semantic networks during REM sleep or it may form a key component of post-awakening, REM sleep inertia, a type of 'dream inertia.' It should be noted, however, that as our findings for positive and negative cue-words were post-hoc and based on smaller samples than were those for other statistical tests, more study is needed to replicate these findings and assess their possible implication in dreaming's involvement in memory consolidation.

In sum, our findings add to a growing body of research demonstrating that REM sleep is associated with emotional memory consolidation and, in particular, to a modification of semantic priming effects. They thus support the notion of a hyperactivation of semantic networks during REM sleep and of a further facilitation of such activation in the post-REM sleep awakening period. Our results point especially to a role for positive emotional stimuli which other work has found to have a facilitating effect on spreading activation in semantic networks. An unexpected negative correlation between priming and time in REM sleep may reflect the activity of an underlying function regulating emotion, such as that predicted by the SRSF model of Walker (2009), whereas the association of priming exclusively with REM sleep awakenings may signal the influence of REM sleep inertia on this cognitive measure.

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2.2 Second Article

Daydreams and nap dreams: content comparisons

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Abstract

Differences between nighttime REM and NREM dreams are well-established but only rarely assessed for daytime REM and NREM nap dreams and rarely compared with daydreams. Fifty-one participants took daytime naps (with REM or NREM awakenings) and provided both waking daydream and nap dream reports. They also provided ratings of the bizarreness, sensory experience, and emotion intensity. Recall rates for REM (96%) and NREM (89%) naps were elevated compared to typical recall rates for nighttime dreams (80% and 43% respectively), suggesting an enhanced circadian influence. All attribute ratings were higher for REM than for NREM dreams, replicating findings for nighttime dreams. Compared with daydreams, NREM dreams had lower ratings for emotional intensity and sensory experience, while REM dreams had higher ratings for bizarreness and sensory experience. Results support using daytime naps in dream research and suggest selective enhancement and inhibition of specific dream attributes by REM, NREM and waking state mechanisms.

Keywords: emotion, REM sleep, NREM sleep, dreaming, daydreaming, naps

Introduction

Validity of a nap paradigm for dream collection

Dreams sampled from nighttime NREM and REM sleep differ in consistent ways. In addition to the fact that the recall of NREM dreams is much lower than that of REM dreams (Nielsen, 2000), NREM dreams are typically shorter, more fragmented and more thought-like whereas REM dreams are longer, more emotional, and more bizarre (Antrobus, 1983; Kaufmann et al., 2006). And although NREM dreams tend to become more like REM dreams later in the night, REM dreams nonetheless continue to differ from NREM dreams in many respects at this time, e.g., they are consistently more emotional (Hobson, Pace-Schott, & Stickgold, 2000; Wamsley, Hirota, Tucker, Smith, & Antrobus, 2007) and more visually salient (Wamsley et al., 2007) than NREM dreams. The time-of-night increase in dreaming vividness for both sleep stages has been explained as due to circadian fluctuations in REM sleep propensity (Nielsen, Kuiken, Alain, Stenstrom, & Powell, 2004; Suzuki et al., 2004) or brain activation (Antrobus, Kondo, Reinsel, & Fein, 1995; Cicogna, Natale, Occhionero, & Bosinelli, 1998; Wamsley et al., 2007) and the REM/NREM differences as due to local stage-related influences that may or may not summate with the circadian influence (Wamsley et al., 2007). Studies have extended nighttime findings about dream recall and length to daytime naps, confirming that dreams are both more frequently recalled and of greater length after REM than after NREM naps (Chellappa, Münch, Blatter, Knoblauch, & Cajochen, 2009; Palagini, Gemignani, Feinberg, Guazzelli, & Campbell, 2004; Suzuki et al., 2004). However, observations about REM and NREM dream content differences are still based almost exclusively on dream reports sampled from nighttime NREM and REM sleep episodes (McNamara et al., 2010). Whether the differences found for nighttime REM and NREM types of dream reports can also be generalized to nap dreams remains unclear and warrants further study.

Assessing the content of REM and NREM dreams comparatively is all the more important in that naps are being used increasingly in studies of sleep-dependent memory consolidation. For example, learning performance improvements similar to those demonstrated for a full night of sleep have also been shown for daytime naps (Lahl, Wispel, Willigens, & Pietrowsky, 2008; Mednick, Nakayama, & Stickgold, 2003). Some such studies go further to

sample dream mentation that accompanies these naps to determine if this mentation is also associated with learning (Wamsley, Tucker, Payne, Benavides, & Stickgold, 2010). Being more easily collected during daytime hours, the content of nap dreams may be especially well-suited for study of memory-related cognitive processes.

Qualitative attributes of dreams and daydreams

Though comparisons of dream mentation sampled from REM and NREM sleep stages at different times of the day have produced a relatively consistent pattern of differences in recall frequency, report length, and some content categories, comparisons between dreaming and daydreaming reports on a number of qualitative attributes have not provided such clear findings. On the one hand, there are general relationships between elements of nighttime dreams and daydreaming style within individuals; for example, a daydreaming style characterized by anxiety and distractibility is correlated with nighttime dreams that are highly bizarre and emotional (Starker, 1974). Further, a qualitative review of studies that have assessed the content of dreams and daydreams (Fox, Nijeboer, Solomonova, Domhoff, & Christoff, 2013) concluded that the two were similar in several respects, i.e., consisting of predominantly audiovisual sensory content (Klinger, 2009; Schredl, 2010), containing emotion (Killingsworth & Gilbert, 2010; Kramer, Roth, Arand, & Bonnet, 1981) reflecting current concerns and long-term memories, and lacking meta-awareness. On the other hand, dream content is distinct from waking daydreams in that dreams contain more unfamiliar settings, bizarreness, and victimization than do waking daydreams (see reviews in Fox et al., 2013; Strauch & Lederbogen, 1999). In particular, bizarre content, including incongruous, discontinuous or impossible events, is more prominent in dreams than in daydreams, although the number of different thematic units constituting the reported experience is higher for morning daydream reports than it is for morning REM reports (Wollman & Antrobus, 1986).

The lack of consistency between studies of dreaming and daydreaming is complicated by the facts that REM and NREM dreams have not yet been compared separately with waking daydreams and that daydreaming is often retrospectively assessed (using various definitions) as opposed to being systematically induced. The use of daytime REM and NREM naps is arguably a preferred method for comparing these different mentation types because it allows contextual

factors, such as time-of-day and the laboratory, to be more rigorously controlled. The present design samples sleep and waking mentation under identical circadian phases and laboratory conditions.

Objectives and hypotheses

As part of a larger initiative assessing whether naps are suitable for sampling and comparing dream mentation from REM and NREM sleep, our study aimed to contrast REM and NREM nap dreams on attributes of bizarreness, emotionality, and sensory experience. The study further aimed to clarify how these REM and NREM dream attributes compare with those of waking daydreams. We expected that: 1) participants would report dream content from both REM and NREM daytime naps; 2) REM nap dreams would have higher self-rated scores of bizarreness, emotional intensity, and sensory experience than would NREM nap dreams; 3) compared with waking daydreams, REM nap dreams would have higher, and NREM nap dreams lower, scores of bizarreness, emotional intensity, and sensory experience.

Materials and Methods

Participants

We recruited 64 healthy participants (25 men, 39 women) between the ages of 18 and 35 (Mean=23.50±4.14) using advertisements and posters. All were screened for self-reported sleep, neurological, and psychological disorders, other chronic illnesses and use of certain medications. They filled out an informed consent form which had been approved by the research ethics committee of the Hôpital du Sacré-Coeur de Montréal.

Procedure overview

General Procedure: Participants arrived at the laboratory at 8 am and were instructed to complete screening questionnaires. Around 8:30 am, participants completed a daydream procedure while relaxing in bed, after which they typed up a daydream report and responded to a questionnaire (detailed below). Participants also completed a short, 5-minute word association task (not reported here).

At 9 am, participants were hooked up to electrodes by a certified sleep technician. Participants were scheduled to begin their 2-hour nap opportunity at 10 am, near the peak of the circadian REM propensity cycle. Participants slept in bedrooms with audio-visual surveillance and a 2-way intercom. Bedrooms were darkened with blinds, and video surveillance was conducted using only UV light.

Participants were awakened after a target of 80 minutes Total Sleep Time. They were awakened with a non-stressful 500-hz tone and dim lighting, and were instructed to immediately type in their dream report and respond to a questionnaire via a computer console that swiveled out from the bed. Participants were awakened either in N2 (NREM) sleep, or 10 minutes into an R (REM) period, depending on which occurred closest to the target of 80 minutes total sleep time. Thus, participants were split into either NREM (N=28) or REM (N=23) groups. Participants who did not sleep adequately (N=2) or who were instructed to remain awake (N=11) were not included in current analyses.

Following the nap, participants had the electrodes removed by a technician, after which they again completed a short word association task. Results of the word association tasks are reported elsewhere (Carr & Nielsen, 2015). Participants were paid $40 for their participation.

Screening Questionnaires: Participants were asked to fill out a series of questionnaires that took approximately 30 minutes including: Pittsburgh Sleep Disorders Questionnaire (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989), State-Trait Anxiety Inventory (Spielberger, Gorsuch, & Lushene, 1970), the Morningness-Eveningness Chronotype Scale (Horne & Ostberg, 1976), and the Short-Version Boundary Questionnaire (Hartmann, 1989). These questionnaires were selected to reveal potential sleep disorders, high anxiety levels, or abnormal chronotype. Results are not further reported here.

Daydream Reports: Participants were instructed to sit in a relaxed position on the bed with their eyes closed for three minutes, during which time they were allowed to think or daydream about anything. Following the three minutes, a 500-hz tone was sounded and the participant was instructed to immediately type in a report of whatever was going through their mind prior to the tone, with a reminder to include as much detail as possible. Following written

reports, participants completed a 10-item questionnaire with 1-9 response scales about daydream attributes such as bizarreness, emotion, and sensory experiences.

Dream Reports: The same reporting procedure was administered following naps. Participants were instructed immediately upon awakening to type in a dream report including as much detail as possible, and then to answer the same 10-item questionnaire about attributes of their dream.

Polysomnography: Participants were recorded by an electrode montage of 6 standard 10-20 EEG channels (F3, F4, C3, C4, O1, O2) referenced to A1, along with 4 EOG and 2 EMG leads. Biosignals were recorded using a Grass 12 Neurodata Acquisition System (-6dB filters with cut offs at 0.30 and 100 Hz) and archived under the control of Harmonie 5.4 software (Stellate Systems, Montreal, Canada). PSG tracings were scored according to current AASM standards (Berry et al., 2012) by an experienced PSG technician. Standard sleep variables (REM min, %REM, NREM min, %NREM, TST) were calculated by in-house software.

Measures

Word count was calculated as the total number of words in the dream and daydream reports that participants typed out immediately after the awakening tone and prior to the questionnaires. Dream and daydream attributes were scored using a 10-item questionnaire; and analyses were conducted on scores for dream recall, negative and positive emotions, sensory experience, and bizarreness. Dream recall was taken from one question about clarity ("How clearly can you recall your mental experience?") on a 1-9 scale, with 1 being no recall and 9 being complete recall. Bizarreness was taken from one questionnaire item that was also scored on a 1-9 scale ("How bizarre was your mental experience?"; 1=not at all, 9=extremely). Emotion was taken from two separate items assessing the intensity of either negative or positive emotions on 1-9 scales ("What was the intensity of the most negative [positive] emotion during this experience?"; 1=not at all, 9=extremely). Sensory experience was a composite score from 3 separate items of the questionnaire, including auditory, visual, and movement experience ("How much of a visual [hearing] [movement] component was there?"; 1=not at all, 9=extremely). One questionnaire item was included as a measure of subjective alertness ("How awake do you feel

right now?"; 1=not at all, 9=extremely). The remaining 2 questionnaire items were specifically related to task performance, and are not further analyzed here.

Statistical Analyses

Mann-Whitney U-tests (MW U) were conducted to look at differences between groups (NREM vs. REM) on self-rated scores of the dream recall and attributes of positive emotion, negative emotion, bizarreness, and sensory experience. Wilcoxon Tests were done to examine within group (NREM, REM) differences between daydream attributes and dream attributes, including positive and negative emotion, bizarreness, and sensory experience.

Results

Sleep architecture measures

There were 28 participants in the NREM group (age=23.07±3.98, 11 men) and 23 in the REM group (age=24.30±4.11, 8 men); there were an additional 13 participants (age=23.00±4.62, 6 men) who stayed awake or achieved only Stage 1 sleep and were not included in further sleep or dream analyses. Groups did not differ in age (NREM vs. REM $t(49)=1.09$, $p=0.28$). Sleep measures were lost for one REM participant, though technician records showed that the participant had achieved REM sleep prior to awakening. This participant was included in the REM group, though sleep comparisons were made for 28 NREM and only 22 REM participants. REM and NREM group comparisons for basic sleep architecture measures revealed that they differed marginally in total sleep time ($t(48)=-1.86$, $p=0.07$), but not in NREM minutes ($t(48)=-0.16$, $p=0.87$). As expected, the REM group had more REM minutes than the NREM group ($t(48)=-3.76$, $p<0.01$).

Table 1. REM and NREM comparisons for basic sleep architecture.

	NREM (N=28)	REM (N=22)			
	Mean	Mean	t_{48}	p	d
Stage 1 (min)	13.96±7.28	12.43±6.03	0.80	0.43	0.23
Stage 2 (min)	30.70±16.70	32.82±10.21	-0.52	0.60	-0.15
Stage N3 (min)	14.48±15.03	14.73±12.47	-0.06	0.95	-0.02
NREM (min)	59.14±20.83	59.98±14.71	-0.16	0.87	-0.05
REM (min)	8.09±9.54	19.09±11.14	-3.76	<0.01*	-1.06
TST	67.23±24.66	79.07±18.78	-1.86	0.07†	-0.54
Stage 1 (%)	26.79±22.69	16.15±7.36	2.11	0.04*	0.63
Stage 2 (%)	42.82±17.30	41.91±10.42	0.22	0.83	0.06
Stage N3 (%)	19.61±20.20	18.39±15.24	0.23	0.82	0.07
NREM (%)	89.23±11.58	76.45±10.55	4.02	<0.01*	1.15
REM (%)	10.77±11.58	23.55±10.55	-4.02	<0.01*	-1.15

*REM and NREM group comparisons did not reveal significant group differences in NREM minutes, though the REM group had more REM minutes. The NREM group had a higher Stage 1 %, and a higher NREM %, whereas the REM group had a higher REM %. (*p<0.05, †p=0.07). d: Cohen's D effect size; TST: total sleep time.*

Dream and Daydream Measures

All participants successfully recalled and reported daydreams and gave daydream ratings and a rating of baseline subjective alertness. Following naps, all participants again gave ratings of subjective alertness. Three NREM participants and 1 REM participant reported no dream recall and were excluded from calculations of dream word count and attribute ratings.

Comparison of NREM and REM group daydreams

Comparisons were conducted to assess baseline differences in daydream attribute ratings and subjective alertness (see Table 2 for means and standard deviations; see Table 3 for statistics).

Table 2. Mean daydream and nap dream measures for NREM and REM groups.

	NREM		REM	
	Daydream	**Nap dream**	**Daydream**	**Nap dream**
	N=28	N=25	N=23	N=22
Alertness	6.11±1.95	5.04±2.13	5.78±1.98	4.35±1.50
Word Count	79.06±61.18	44.17±32.47	69.33±31.23	101.57±115.19
Bizarreness	2.96±1.60	3.00±2.16	2.65±1.53	5.41±2.77
Negative	3.46±2.03	2.48±1.71	3.04±1.82	3.86±2.12
Positive	4.89±2.28	3.36±2.04	4.96±2.58	5.41±2.20
Sensory	13.71±5.18	11.16±5.93	13.96±4.66	17.64±6.09

REM and NREM groups did not differ on any measure, including subjective alertness (p=0.51), word count (p=0.93), bizarreness (p=0.42), negative emotion (p=0.41), positive emotion (p=0.84), and sensory experience (p=0.91).

NREM and REM groups did not differ on subjective alertness after awakening (=0.28), suggesting that sleep inertia effects between the two groups did not differ. Altogether, 89±31% of NREM participants and 96±21% of REM participants reported having some dream recall—an insignificant difference (p=0.70).

Table 3. Mann Whitney group comparisons of daydream and nap dream measures.

	Daydream (NREM v REM)				Nap dream (NREM v REM)			
	U	Z	p	r	U	Z	p	r
Alertness	287.0	-0.66	0.51	-0.09	265.5	1.07	0.28	0.15
Word Count	132.5	0.09	0.93	0.01	144.5	2.29	0.02*	0.33
Bizarreness	279.5	-0.80	0.42	-0.11	132.5	3.04	<0.01*	0.44
Negative	278.5	-0.82	0.41	-0.12	167.0	2.30	0.02*	0.34
Positive	311.0	0.21	0.84	0.03	134.5	3.00	<0.01*	0.44
Sensory	316.0	-0.11	0.91	-0.02	121.5	3.27	<0.01*	0.48

*(Mann-Whitney U tests; *p<0.05).*

Group comparisons of the 25 NREM and 22 REM participants with dream recall revealed that REM nap dream reports had significantly higher word counts than did NREM nap

dream reports (p=0.02; see Table 3). Further, relative to NREM nap dreams, REM nap dreams were rated higher on all content measures: bizarreness (p<0.01), negative emotion (p=0.02), positive emotion (p<0.01), and sensory experience (p<0.01; see Table 2 for means and Table 3 for statistics).

Comparison of daydream and nap dream attributes

Within group comparisons were conducted to assess differences between daydreams and NREM and REM nap dreams (see Table 2 for means and Table 4 for statistics). Comparisons of both daydreams and nap dreams from the NREM group revealed that ratings for positive emotion and sensory experience were lower for NREM nap dreams (both p<0.05) than for daydreams; ratings for negative emotion were also marginally lower (p=0.05), while ratings for bizarreness did not differ (p=0.76).

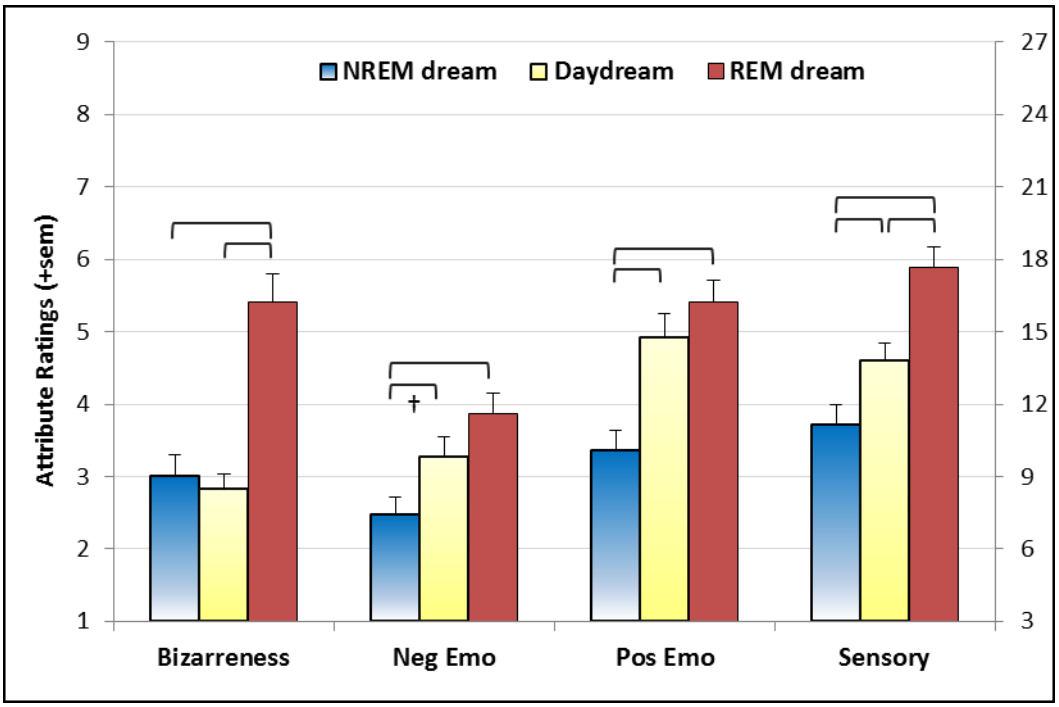
Table 4. Within group comparisons of daydream and nap dream measures.

	NREM (daydream v dream)			REM (daydream v dream)		
	Z	p	r	Z	p	r
Alertness	2.46	0.01*	0.49	2.78	<0.01*	0.58
Word Count	0.97	0.33	0.19	0.07	0.94	0.01
Bizarreness	0.30	0.76	0.06	3.38	<0.01*	0.72
Negative	1.94	0.05†	0.39	1.05	0.30	0.22
Positive	2.21	0.03*	0.44	0.35	0.72	0.07
Sensory	1.97	<0.05*	0.39	1.96	<0.05*	0.42

*Within group comparisons (Wilcoxon tests; *p<0.05).*

Within the REM group, ratings for bizarreness and sensory experience were higher for REM nap dreams than for daydreams (p<0.05); however, the two types of ratings did not differ for either negative (p=0.30) or positive (p=0.72) emotion.

Figure 1. Ratings of bizarreness, negative and positive emotion, and sensory experience for daydream, NREM and REM nap dream reports.



Ratings of bizarreness, negative and positive emotion (1-9 scale, left axis), and sensory experience (3-27 scale, right axis) for daydream, NREM nap dream and REM nap dream reports. Daydream ratings from NREM and REM groups did not differ and were collapsed into one rating. REM nap dream reports were given higher bizarreness and sensory ratings than were daydream reports; NREM nap dream reports were given lower positive and negative emotion and sensory ratings than were daydream reports. REM nap dream reports were given higher ratings than were NREM nap dream reports on all attributes. (†p=0.05, all other brackets p<0.05)

Discussion

Dream Recall and Mentation Attributes of Daytime Naps

Our finding of frequent dream recall from both REM and NREM daytime naps supports our first and most general expectation that dream recall from naps would be at least as frequent as for nocturnal sleep. It thus supports the notion that daytime naps are suitable for sampling and comparing dream mentation from REM and NREM sleep stages. That dream recall rates for

NREM (89%) and REM (96%) naps were even higher than average rates seen for nocturnal sleep (43% and 80% respectively; see Nielsen, 2011 for review) and more similar to rates seen for late night NREM (90.6%) and REM (95.0) awakenings (e.g., Cicogna et al., 1998) suggests that the daytime naps in our protocol, which all took place between 11:30 am and 12:00 pm, may have taken place close to the circadian peak of the REM propensity cycle (Dijk, Shanahan, Duffy, Ronda, & Czeisler, 1997). The latter is thought to be correlated with higher dream recall and a greater predominance of some mentation attributes such as character interactions, emotional contents, and dream vividness (see Nielsen, 2011 for review). Such across-the-night differences have been shown to increase for both REM (Cohen, 1977; Domhoff & Kamiya, 1964; Kramer, McQuarrie, & Bonnet, 1980; Rosenlicht, Maloney, & Feinberg, 1994) and NREM (Antrobus et al., 1995; Suzuki et al., 2004; Wamsley et al., 2007) dreams even though some REM/NREM differences are maintained (e.g., Wamsley et al., 2007; Zimmerman, 1970).

Accordingly, although we achieved relatively frequent dream recall from NREM naps, REM and NREM nap dreams nonetheless differed in word count, with REM reports being on average twice as long as NREM reports. Further, NREM report ratings were lower on all qualitative attributes than were REM report ratings. Thus, the difference in word count we observed replicates a word count difference with the same magnitude for afternoon REM and NREM naps (Palagini et al., 2004) while our finding of elevated scores for bizarreness in REM relative to NREM nap dreams directly replicates similar findings for REM and NREM nighttime dreams (Casagrande, Violani, Lucidi, Buttinelli, & Bertini, 1996; Porte & Hobson, 1986; Wamsley et al., 2007). The latter finding may, however, be inconsistent with the finding that more late NREM2 dreams contain instances of space-time distortions (a more limited category of bizarreness) than do REM dreams (Cicogna et al., 1998). Finally, our findings of greater positive and negative emotion ratings in REM than in NREM nap dreams and the elevated scores for sensory experience of REM naps parallel reports of more elaborate and vivid experience of nighttime REM dreams when compared to NREM dreams (Cai, Mednick, Harrison, Kanady, & Mednick, 2009; Foulkes, 1962; Smith et al., 2004; Wamsley et al., 2007). Altogether, these results suggest that the REM and NREM dream mentation of daytime naps may be studied comparatively much as they are with nocturnal dreams and that the same REM/NREM content differences reported in many studies of nocturnal dreams may persist. However, additional

research comparing nighttime and daytime nap dreams is needed to determine if both REM and NREM types of report reflect the influence of an underlying circadian activation factor in addition to a local stage-related factor. We expect that such comparisons may demonstrate that morning, but not afternoon, nap dreams will prove to be more visually and emotionally vivid than will nighttime dreams. More comparative studies that sample dream content at different, representative points along the REM propensity curve (e.g., Suzuki et al., 2004) are needed to clarify how daytime and nighttime dreams resemble and differ from one another.

Comparison of Daydreams and Nap Dreams

Comparisons between daydreams and nap dreams illustrate a pattern of similarities and differences consistent with the possibility that some imagery attributes are selectively enhanced by REM sleep dreaming mechanisms (Domhoff & Fox, 2015; Fox et al., 2013; Hartmann, 1996; Klinger, 2009; Koike, Kan, Misaki, & Miyauchi, 2011; Smallwood & Schooler, 2015; Zimmerman, 1970) whereas others are selectively inhibited by NREM sleep mechanisms. Specifically, that the emotional intensity (both positive and negative) of REM nap dreams did not differ from that of daydreams as predicted and was relatively lower in NREM nap dreams is consistent with the notion that waking emotional processes remain active during REM but are inhibited during NREM sleep. Similarly, that the intensity of sensory experience in REM nap dreams was increased relative to daydreams whereas in NREM nap dreams it was decreased is consistent with the possibility that mechanisms governing the sensory vividness of imagery are enhanced in REM and inhibited in NREM sleep. Finally, that bizarreness was higher in REM nap dreams than in daydreams, but did not differ between NREM nap dreams and daydreams, suggests that imagery bizarreness mechanisms are enhanced only during REM sleep. Together, these findings indicate that—relative to daydreams—different mechanisms of imagery generation are differentially modulated across sleep/wake states, i.e., in REM nap dreams, emotion is maintained while bizarreness and sensory experience are both enhanced and, in NREM nap dreams, bizarreness is maintained while emotion and sensory experience are both suppressed.

Reasons for these differential patterns of imagery modulation are still not known. One possible explanation derives from recent models linking dreaming to waking spontaneous

thoughts or 'mind-wandering' (Domhoff, 2011; Domhoff & Fox, 2015; Fox et al., 2013; Ioannides, Kostopoulos, Liu, & Fenwick, 2009; Pace-Schott, 2007, 2010; Wamsley, 2013) which considers spontaneous imagery to span a continuum from daytime mind-wandering, which includes a variety of daydreaming, fantasy, imagination and other types of non-instrumental cognitions on one extreme, to dreaming on the other extreme (Fox et al., 2013; Hartmann, 1996). By this theory, dreaming constitutes a more 'intensified' form of mind-wandering even though both dreaming and mind-wandering may derive from the same neurophysiological substrate—the default mode network (Domhoff, 2011; Domhoff & Fox, 2015; Wamsley, 2013). As the elevated bizarreness and sensory experience we observed for REM nap dreams relative to daydreams matches what was observed in a qualitative review (Fox et al., 2013, pp. 10-11), these findings could be taken to support such a theory. However, the mind-wandering theory is not yet comprehensive enough to adequately explain the ensemble of our findings including: 1) why NREM nap dreams showed lower levels of sensory experience and emotion than did daydreams; 2) why REM nap dreams exceeded NREM nap dreams so markedly on all attributes; 3) why REM nap dreams and daydreams failed to differ on the positive and negative emotions measures when some research suggests that dreams contain more negative emotions than waking event reports (Nielsen, Deslauriers, & Baylor, 1991) while mind-wandering contains more positive emotions (Fox et al., 2013; Schredl, 2010). Also, the fact that the default mode network is only partially activated during REM sleep (Pace-Schott, 2010) places these mind-wandering theories on a questionable neurophysiological footing. In sum, while the mind-wandering hypothesis is a novel and promising attempt to unify different forms of imagery generation, it lacks both the phenomenological and neurophysiological detail to explain all findings from the present contrasts between REM nap, NREM nap and daydream imagery.

Implications for memory consolidation

There is substantial evidence—including evidence from daytime napping studies—that the amounts and microstructural features of REM and NREM sleep contribute to memory consolidation beyond what is seen during an equivalent amount of wakefulness (Breton & Robertson, 2014). However, evidence that the dreams from REM and NREM sleep are a necessary component of this consolidation mechanism is more controversial. A few studies have

reported associations between dream content and overnight memory improvement (de Koninck, Christ, Hebert, & Rinfret, 1990; Wamsley et al., 2010) or between dream emotion and overnight emotion regulation (Cartwright, Luten, Young, Mercer, & Bears, 1998; Lara-Carrasco, Nielsen, Solomonova, Levrier, & Popova, 2009). But such studies provide conflicting findings and remain largely unreplicated. To illustrate, Smith and Hanke (2004) found that participants who were administered the Mirror Tracing Task, a known REM-dependent procedural task, together with administration during REM sleep of a task-associated stimulus (auditory clicks), reported longer dreams and more changes in dream content (metaphoric representations of the learned task) than did control participants. In contrast, we found that better overnight improvement on the Mirror Tracing Task was associated with low rates of dream recall and changes in negative dream emotion (Dumel et al., 2015). In brief, research remains inconclusive on the question of dreaming's implication in memory consolidation.

Nonetheless, although the present findings do not demonstrate a role for dreaming in memory consolidation, they do indicate that such a role may be studied as validly—and perhaps even more practically—using morning nap dreams. In particular, the facts that dream recall from morning naps is so abundant and that content profiles of REM and NREM naps are similar to those of nighttime REM and NREM sleep both support the use of morning naps as a paradigm for assessing dreaming's role in memory consolidation. Even more importantly, the morning naps protocol permits a more stringent control over waking state comparison groups for such memory studies. At present, comparisons of mental content between sleeping participants and waking controls generally do not specify the nature of the waking state to which sleep stages are compared. Control participants might be mind-wandering, fretting, retrieving autobiographical memories, making plans for the day, or any number of other cognitive activities. The use of a daydreaming condition such as ours assures that all subjects are engaged in similar types of mental activity during the control interval and that such mental activity is similar in at least superficial ways to dreaming—thus providing a controlled conservative comparison for the dreaming conditions.

Further, our sleep/wake state comparisons suggest some features of nap dreaming and daydreaming content that might or might not be differentially implicated in memory consolidation. In particular, the relatively elevated scores for REM nap dreams on sensory

experience and bizarreness point to two attributes that are especially likely candidates for a memory consolidation function. The observed predominance of sensory experience—which consists of visual, auditory and kinesthetic modalities—is entirely consistent with the fact that the REM sleep state is associated with the consolidation of visuo-motor and procedural learning tasks (Aubrey, Smith, Tweed, & Nader, 1999; Plihal & Born, 1999), both of which may rely on activation of sensorimotor networks. Such activation of sensorimotor networks may enable a maximum degree of apparent sensory immersion in the experience through the phenomenology of REM dreaming.

Similarly, relatively higher ratings of bizarreness in REM nap dreams than in either daydreams or NREM nap dreams could be indicative of an increases in the associativity of semantic memory networks during REM sleep (Cai et al., 2009; Carr & Nielsen, 2015). This hyper-associativity, coupled with an attenuation of executive function, may also enable a more complete immersion in novel and bizarre dream experiences (Christoff, Gordon, Smith, Vartanian, & Mandel, 2011; Fox et al., 2013). In contrast, the lower bizarreness scores for daydreams could reflect the operation of more structured networks underlying conscious control (Corno, 1986) and task-focused attention (Smallwood, Obonsawin, & Heim, 2003). Similarly, low bizarreness ratings in NREM nap dreams could reflect the operation of memory networks that are similar to those of waking thought and implicated in direct replays of episodic memories.

Recently, studies on sleep and memory have found that REM sleep is particularly important for the consolidation and regulation of emotional memory (Groch, Wilhelm, Diekelmann, & Born, 2013; Nishida, Pearsall, Buckner, & Walker, 2009), which raises the possibility that the emotions of REM dreams participate in this consolidation function. This could take place in a manner similar to the emotional enhancement of memory (EEM) that occurs during wakefulness when dysphoric emotional stimuli—unrelated to the target stimuli—are presented during a memory task (Steidl, Razik, & Anderson, 2011; Weymar, Schwabe, Löw, & Hamm, 2012) or up to 30 min post-learning (Judde & Rickard, 2010; Nielson & Powless, 2007). For example, when unrelated negative stimuli are presented during the Mirror Tracing Task, a sleep-related memory benefit is superior to when more neutral stimuli are presented (Javadi, Walsh, & Lewis, 2011). Such findings for negative emotions are consistent with our own findings that negative dream emotion correlates positively with degree of overnight

improvement on the Mirror Tracing Task (Dumel et al., 2015), and with overnight maintenance of emotional reactions to fearful slides (Lara-Carrasco et al., 2009). In the present study, however, emotional intensity ratings for REM nap dreams were of only moderate intensity (3.9 to 5.4 out of 8), equivalent to those for daydreams, and not assessed with respect to memory. So we might predict in future studies that the emotional content of these two types of imagery would be associated equally well with a facilitation of memory consolidation but that more intensely emotional dreams would have an even stronger facilitative effect.

Unlike REM sleep, however, NREM sleep seems to be involved in direct episodic memory consolidation, perhaps largely in the absence of emotional influences (Smith, 2001). NREM sleep mechanisms may thus actively inhibit emotional experience, resulting in lower emotional intensity than that of either daydreams or REM nap dreams.

In sum, content comparisons of NREM dreams, daydreams and REM dreams reveal patterns of similarities and differences that suggest differential modulation of content attributes during the 3 states. Some findings are consistent with mind-wandering theories of dreaming although much more research is needed. The findings also support the use of nap dreams in the study of memory consolidation functions of dreaming and suggest some attributes that may be particularly likely to reveal such functions.

Limitations of the study

The study was limited in a few respects. First, that the dream report analyses were conducted between-groups as opposed to within-groups raises the possibility that findings were due to inherent differences in our groups; however, baseline comparisons suggested this was not the case. Second, as with the majority of current scientific sleep research, the experiment was conducted in a laboratory as opposed to a home environment and may thus not be representative of all dreaming; however, this risk is compensated by the fact that the collection of nap dreams as opposed to nighttime dreams was easier and more convenient for both technicians and participants. Finally, while we attempted to induce daydreaming in a methodologically consistent fashion, future research could improve upon the procedure, perhaps with the use of sensory deprivation or visual suggestion.

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2.3 Third Article

Nightmare sufferers show atypical emotional semantic associations and prolonged REM sleep-dependent emotional priming

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Abstract

Study Objectives: To investigate whether nightmare sufferers exhibit an abnormal network of emotional semantic associations as measured by a recently developed, REM sleep-sensitive, associational breadth (AB) task.

Design: Nightmare sufferers (NM) were compared to healthy controls (CTL) for their performance on an emotional AB task containing positive and negative cue-words both before and after a nap containing REM sleep. AB was assessed in both a priming condition, where cue-words had been explicitly memorized prior to sleep, and a non-priming condition, where cue-words had not been memorized. Participants were assessed again one week later.

Setting: Sleep laboratory with polysomnographic recording, Hôpital du Sacré-Coeur de Montréal

Participants: Twenty-eight participants between the ages of 18 and 35 (Mage=23.3±3.43).

Measurements and Results: The NM group scored higher than the CTL group on both positive and negative AB, with group differences persisting at one week retest. However, the two groups did not differ as expected on the AB priming effect following REM sleep. Both groups showed decreased AB priming for negative cue-words and increased AB priming for positive cue-words. However, the NM group maintained these effects 1 week later whereas the CTL group did not.

Conclusions: NM sufferers may have broader than normal emotional semantic networks in wake, a difference possibly contributing to the perception that this group is more creative. The fact that the AB priming effect is maintained at 1 week retest for NM sufferers suggests that the presence of frequent nightmares may alter REM-sleep dependent emotional processes over time.

Keywords: associative memory, emotion, REM sleep, nightmares, psychopathology

Introduction

Nightmares, sleep and emotional cognition

Nightmares are powerful unpleasant dreams associated with feelings of threat, anxiety, fear, or other negative emotions that are clearly recalled upon awakening and that arise primarily during late night REM sleep (American Psychiatric Association, 2013). Individuals suffering from frequent idiopathic nightmares may have disturbed sleep patterns, both during the nightmare experience itself and potentially in its absence (Fisher, Byrne, Edwards, & Kahn, 1970; Germain & Nielsen, 2003; Marshall, Acheson, Risbrough, Straus, & Drummond, 2014; Simor, Bodizs, Horvath, & Ferri, 2013; Simor, Horváth, Gombos, Takács, & Bódizs, 2012). For example, during an ongoing nightmare, subjects may experience increased HR, eye movements, and shortened breath (Fisher et al., 1970; Goodenough, Witkin, Koulack, & Cohen, 1975); REM periods not marked by nightmares have also shown altered structure, including increased REM latency, or increased high alpha spectral power (10-14.5 Hz; Nielsen et al., 2010; P. Simor, Horváth, Ujma, Gombos, & Bódizs, 2013). Such disturbances may be disruptive to emotional regulation mechanisms provided by sleep.

REM sleep in particular is theorized to regulate emotion through reduction in amygdala activation, while simultaneously improving cognitive processing of emotion through increased functional mPFC connectivity (Ochsner & Gross, 2005). Consequently, research shows that sleep loss leads to increased emotional reactivity as measured both physiologically and behaviorally, as well as decreased outward expression and cognition of emotion by sleep-deprived individual themselves (McGlinchey et al., 2011; Minkel, Htaik, Banks, & Dinges, 2011). This pattern mirrors clinical findings that patients with frequent nightmares suffer from both hyperarousal and alexithymia, a deficit in cognitive labelling of emotion (Nielsen, Levrier, & Montplaisir, 2011). Further, nightmare sufferers are prone to affective disorders, including anxiety and depression, implicating a relationship between nightmares and dysfunctional emotion processing (Levin & Nielsen, 2007). They also have increased cognitive perseveration on a word fluency task and poor performance on an emotional stroop task (Simor, Bodizs, et al., 2013; Simor, Pajkossy, Horváth, & Bódizs, 2012). Thus, frequent nightmares may contribute to

deficits in both the affective and cognitive domains, although more research is warranted to specifically assess emotional cognition.

REM sleep associative integration of emotional memory

A largely unexplored avenue of research in the nightmare population is the study of REM-dependent emotional memory consolidation. One generally supported and relevant theory of REM sleep function is in the adaptive integration of emotional experiences within the vast autobiographical network. The unique neurophysiological state of REM sleep allows activation of emotional memory traces within an environment of increased associative cortical connections, thus promoting emotional memory integration (Diekelmann & Born, 2010; Hu, Stylos-Allan, & Walker, 2006; Landmann et al., 2014; Payne, Chambers, & Kensinger, 2012; Payne, Stickgold, Swanberg, & Kensinger, 2008). A great deal of research supports the role of REM sleep in emotional memory consolidation, such as in the consolidation of fear and safety memories or of the negative component of complex pictures (Marshall et al., 2014; Payne et al., 2012). At the same time, several behavioral experiments support an associative function for REM sleep, showing increased associative capacity immediately upon awakening from REM sleep and improved performance on associative tasks that had been primed prior to a REM sleep nap (Cai, Mednick, Harrison, Kanady, & Mednick, 2009; Stickgold, Scott, Rittenhouse, & Hobson, 1999; Walker, Liston, Hobson, & Stickgold, 2002). Both of these findings support claims that REM sleep enables enhanced access to associative semantic content. Notwithstanding such findings—and theoretical speculations about an emotional integration function of REM sleep—the interaction between emotional memory and associative access has not been thoroughly studied.

Our recent study specifically assessed the effects of REM sleep on associative integration of emotional semantic stimuli, as measured by an Associational Breadth (AB) task, among healthy college students (Carr & Nielsen, 2015). Following a morning nap, participants were asked to provide word associations to emotional cue-words that they had memorized prior to sleep. Participants who had had REM sleep during their nap gave less common word associations (scored relative to word associate norms; Altarriba, Bauer, & Benvenuto, 1999). than did participants who had had only NREM sleep during their nap or who had stayed awake.

This finding suggests that the emotional words studied prior to sleep were consolidated within a broad semantic network exclusively during REM sleep. Further, this priming effect was particularly strong for positive, compared to negative, cue-words. The positively valenced cue-words were thought to engender increased spread of activation in REM sleep, similar to an effect observed in waking state priming studies. Specifically, induction of a positive mood facilitates spread of activation (Topolinski & Deutsch, 2013), improves success with Remote Associates Task solutions (Corson, 2002; Haänze & Hesse, 1993; Isen, Daubman, & Nowicki, 1987), and increases the unusualness and diversity of word associations (Isen, Johnson, Mertz, & Robinson, 1985). Further, positive stimuli promote faster speed of semantic access (Zdrazilova & Pexman, 2013). Thus, positive cue-words in our study may have led to increased breadth and speed of spreading activation in REM sleep.

These findings support the validity of the emotional AB task as sensitive to both REM sleep and the emotional valence of experimental stimuli. It is thus an appropriate task for assessing REM sleep-related emotional processes among frequent nightmare sufferers. However, the available literature points to two distinct hypotheses about whether NM sufferers would be expected to show an increase or a decrease in breadth of emotional semantic associations.

Restricted Associational Breadth in the NM sufferer

The most poignant symptom of the nightmare sufferer, the nightmare experience itself, is composed of rather repetitive and perseverative content, suggesting that NM psychopathology is characterized by restricted emotional semantic access. The nightmare experience is striking in the vividness of its pseudosensory imagery and overwhelming in the intensity of its emotional expression. The nightmare often depicts an unrelenting threat, be it due to pursuit by an aggressor, an out of control car, or an immanent tidal wave. The nightmare's main theme and imagery seem to grow more potent and imposing over time, with an increase in emotional arousal, and a resistance to the associative fluidity that normally permeates dreams (Hartmann, 2011). This characterization of nightmares as associationally restricted coincides with findings in the waking cognitive literature that show that positive emotion increases associative access while negative emotion restricts and slows it (Fredrickson, 2001; Selby, Anestis, & Joiner,

2008). Thus, the nightmare may reflect a temporary failure of REM processes to express or integrate a dysphoric emotional memory. Given this explanation, we would expect the presence of nightmares to correlate with reduced associational breadth and longer associational reaction times on the baseline AB task and a blunting of REM sleep-dependent emotional priming.

Expanded Associational Breadth in the NM sufferer

A second possible explanation of NM pathology is that frequent nightmare sufferers are characterized by a broader than normal access to emotional semantic networks. NM sufferers report higher than average recall of positively toned dreams, e.g., non-nightmare dreams and other "intensified" dreams (Levin, 1994; Spadafora & Hunt, 1990), such as lucid dreams, containing self-reflective awareness and subtle kinesthetic imagery, and archetypal dreams, containing blissful emotion and, often, spiritual encounters. Even in the waking state, NM participants report more bizarreness in their daydreams—bizarreness has been likened to associational breadth (Carr & Nielsen, 2015; Walker, Liston, Hobson, & Stickgold, 2002). NM sufferers are also characterized by "thin boundaries", a personality construct that includes creativity and artistic expression, both of which seem to draw more flexibly and frequently upon unusual associations (Hartmann, 2011). Together, such findings support an expectation that NM sufferers may demonstrate an increase in associational processing.

In sum, while research supports a role of REM sleep in the associative integration of emotional memory, any potential consequence of frequent nightmares on this process is unknown. On the one hand, the nightmare experience seems to reflect associative restriction imposed by intense negative emotion; on the other hand, nightmare sufferers often report positive and bizarre dreams, and are frequently characterized as creative, artistic individuals. Assessment of their performance on an emotional AB task both before and after REM sleep will shed light on waking and REM sleep-dependent processes.

Objectives & hypotheses

To determine if the presence of persistent NMs is associated with either restricting or broadening of access to emotional semantic networks we used a nap protocol and a recently developed task for assessing semantic associational breadth (AB) in response to negative and positive emotional words (Carr & Nielsen, 2015). Our objective was to assess baseline and REM

sleep-dependent changes in emotional word associations among frequent nightmare sufferers (NM) and controls (CTL). We also assessed whether group differences were maintained at one week follow up.

Hypotheses: Current evidence is scarce but leans toward the hypothesis that NM participants will show restricted associative access, particularly in response to negative cue-words, on an emotional Associational Breadth task both without and with REM-sleep dependent priming i.e., 1) lower AB scores, particularly for negative cue-words; 2) slower Reaction Times (RT) for associational responses; 3) lower scores on the REM sleep-dependent Priming Effect, particularly for negative cue-words; 4) slower RTs for Priming Effect responses.

All effects are expected to be maintained for NM participants after a 1-week delay.

Materials and Methods

Participants

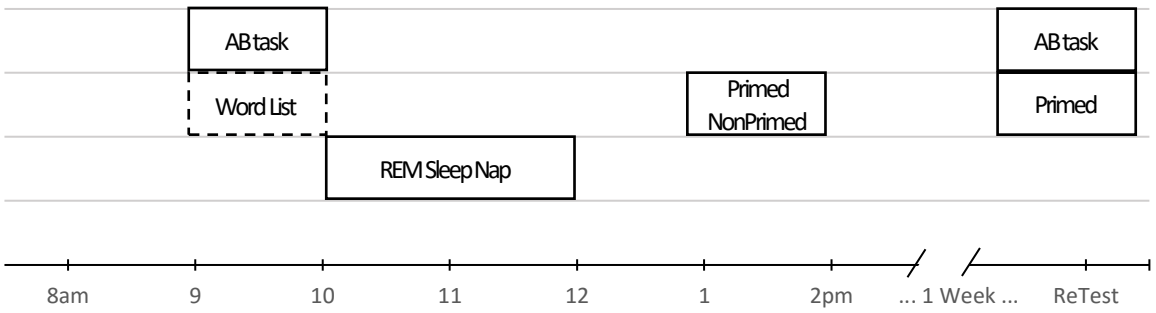
Twenty-eight participants (20 female) between the ages of 18 and 35 (Mage=23.3±3.43) were recruited for a nap study using advertisements and posters. CTL participants reported recalling fewer than 1 nightmare per month for the past five years, whereas NM participants reported recalling at least 2 nightmares per week for the past 6 months. Potential participants underwent a telephone screening questionnaire; exclusion criteria included self-reported sleep disorders other than nightmare disorder, neurological, psychological, or other chronic illnesses, addictions, use of certain medications, or other conditions that interfere with sleep. Participants completed an informed consent form that had been approved by the ethics committee of the Hôpital du Sacré-Coeur de Montréal.

Procedures

Participants arrived at 8 am and immediately filled out informed consent forms and completed a series of questionnaires that took approximately 30 minutes (not reported here).

At 9 am, participants completed an Associational Breadth (AB) task with 4 negative and positive cue-words, and studied an 8-item word list (see Figure 1). They also completed a waking daydream procedure (daydream results are not reported here).

Figure 1. Study Design



Participants arrived at 8am and completed informed consent. At 9am, they completed an AB task and studied a word list. Between 10am and 12pm, they took a PSG-recorded nap with an awakening 10 minutes into REM sleep. One hour post awakening, they completed an AB task consisting of cue-words they had studied prior to sleep (Primed), along with novel cue-words (NonPrimed). They returned 1 week later for a ReTest on the AB task and the Primed AB task.

At 10 am, a sleep technician attached an electrode montage for polysomnography and performed biocalibration. Subsequently, participants were given a 2-hour opportunity to nap. A technician trained in sleep stage scoring monitored each nap and awakened participants 10 minutes into REM sleep provided a minimum of 50 minutes of total sleep time had elapsed.

Upon awakening, participants were asked to recall their sleep-related cognitions ('Please recall what was going through your mind prior to the beep'), and to complete a 14-item questionnaire about the content of that experience (not reported here). The electrode montage was then removed.

Approximately 1 hour post-awakening, participants again completed an AB task which this time contained cue-words familiar to them from the previous memorization task (Primed), along with novel cue-words (NonPrimed) which were used to calculate a relative Priming Effect (Primed minus NonPrimed AB scores). Participants were then free to leave.

Participants returned to the laboratory 1 week later to complete the AB task again with novel cue-words for comparison with initial AB performance; they also completed a second Primed AB task for comparison with the first Primed AB task.

Polysomnography

Participants slept in bedrooms with continuous audio-visual surveillance and a 2-way intercom. They were recorded with an electrode montage of 6 standard 10-20 EEG channels (F3, F4, C3, C4, O1, O2) referenced to A1, 4 EOG (vertical and horizontal channels), 4 EMG channels (chin, corrugator), and 3 EKG channels. Biosignals were recorded using a Grass M12 and Grass M15 Neurodata Acquisition Systems (-6dB filters with cut-offs at 0.30 and 100 Hz) and archived under the control of Harmonie 5.4 software (Natus Medical Inc., Montreal, Canada). PSG tracings were scored according to current AASM standards (Berry et al., 2012) by an experienced PSG technician and standard sleep variables (REM min, %REM, NREM min, %NREM, TST) were calculated by in-house software.

Associational Breadth task (emotional version)

The AB task is designed to assess levels of, and changes in, semantic associational activation, i.e., the extent to which a cue-word leads to more remote associations in a semantic network. The emotional version of the task was previously found to be REM sleep-dependent, and was thus chosen for the current protocol. The task is scored in comparison to empirically determined norms for the typicality of associations that are given by participants in response to common emotion cue-words (Altarriba et al., 1999; Mednick, 1962).

On each administration of the AB task, 2 positive and 2 negative cue-words, each randomly selected without replacement from a set of 16 emotion cue-words, were presented. Participants were required to respond with the first three words that came to mind as being meaningfully associated to the presented cue-word. A maximum of 30 seconds was allowed to respond; a countdown clock on the screen displayed the time remaining to type their responses. The presentation software ("Inquisit 4.0.0.1," 2012) recorded all words typed by participants and recorded the total time taken for the participant to enter all three responses. Reaction time (RT) was defined as the time in milliseconds between the start of the countdown clock to the third press of the Enter key (corresponding to submission of the 3rd word association).

Participant responses were later scored by an experimenter working from an empirically determined table of the 3 most common word associates given for each cue-word (Altarriba et al., 1999). Any participant response that was not an established common associate for the cue-

word was thus considered to be atypical and given a score of 1. Accordingly, an AB score from 0 to 3 could be assigned to each cue-word. AB scores for the 2 negative cue-words of each task were then summed and converted to percentages as were the scores for the 2 positive cue-words.

Priming Effect: Prior to sleep, participants were instructed to memorize a word list of 4 negative and 4 positive cue-words, each randomly selected without replacement from the set of 16 cue-words. These 8 words were presented in randomized order, for 4 sec/word, for three sequential presentations. The Primed AB tasks consisted of cue-words drawn from this word list, whereas the NonPrimed task consisted of completely new 4 cue-words.

AB scores for the NonPrimed and Primed tasks were first calculated as described above to produce percentages. Subsequently, a Priming Effect was calculated by subtracting NonPrimed from Primed scores for negative and positive cue-words separately. Thus, positive scores indicate that Primed cue-words produced more uncommon associates than did NonPrimed cue-words; negative scores indicate the opposite.

Reaction Time: For all AB tasks, reaction time (RT) measures were recorded as the total time taken for participants to give three responses to each cue-word. An average time was calculated separately for the 2 negative cue-words and 2 positive cue-words of each AB task.

For the Priming Effect, differences in reaction time (Priming Effect RT) were calculated as the difference between NonPrimed and Primed response times (Priming Effect RT=Primed-NonPrimed).

Statistics

Hypothesis 1: Associational Breadth: A 2 group (NM, CTL) x 2 cue-type (negative, positive) x 2 time-point (Test, ReTest) ANOVA tested the hypothesis that NM sufferers would have lower AB scores than CTLs, particularly for negative cue-words, and that this effect would be maintained over time. Specific t-test comparisons were done to examine between and within group differences.

Hypothesis 2: Priming Effect: A 2 group (NM, CTL) x 2 cue-type (negative, positive) x 2 time-point (Test, ReTest) ANOVA with Priming Effect as the dependent measure tested the hypothesis that NM sufferers would have lower Priming Effects than CTLs, particularly for

negative cue-words; t-test comparisons were used to assess specific between and within group differences.

Hypothesis 3: Associational Breadth Reaction Time: A 2 group (NM, CTL) x 2 cue-type (negative, positive) x 2 time-point (Test, ReTest) ANOVA tested the hypothesis that nightmare sufferers would have slower Reaction Time (RT) overall, particularly for negative cue-words, and that this effect would be consistent over time. Specific t-test comparisons were done to look at between and within group differences.

Hypothesis 4: Priming Effect Reaction Time: A 2 group (NM, CTL) x 2 cue-type (negative, positive) x 2 time-point (Test, ReTest) ANOVA with Priming Effect RT as the dependent measure tested the hypothesis that NM sufferers would have slower RT scores than CTLs, particularly for negative cue-words, and that this effect would be consistent over time; t-test comparisons were used to assess specific between and within group differences.

Results

Sleep Structure

Participants slept for a target of 80 minutes of total sleep time with an awakening 10 minutes into REM sleep. 4 CTL subjects were excluded for not sleeping or for waking up well before the target time had elapsed. Groups did not differ in minutes of NREM sleep ($p=0.80$), minutes of REM ($p=0.31$), or TST ($p=0.55$). However, the NM group had significantly lower REM efficiency ($t(22)=-2.21$, $p=0.04$). See Table 1 for means.

Table 1. Sleep stage measures for naps of Nightmare and Control groups.

Table 1. Sleep stage measures for naps of Nightmare and Control groups.

	NM			CTL			t	p	
TST	82.11	±	21.31	88.20	±	27.86	-0.61	0.55	
Sleep Efficiency	91.35	±	7.99	90.09	±	12.30	0.31	0.76	
NR1 (min)	13.75	±	6.38	14.60	±	11.06	-0.24	0.81	
NR2 (min)	38.36	±	18.14	37.10	±	20.56	0.16	0.88	
NR3 (min)	13.14	±	16.03	16.10	±	12.08	-0.49	0.63	
NREM (min)	65.25	±	22.24	67.80	±	27.62	-0.25	0.80	
REM (min)	16.86	±	8.28	20.40	±	8.10	-1.04	0.31	
NR1 (%)	18.14	±	10.15	18.01	±	15.16	0.02	0.98	
NR2 (%)	46.53	±	12.82	40.28	±	12.53	1.19	0.25	
NR3 (%)	14.13	±	16.67	16.56	±	12.48	-0.39	0.70	
NREM (%)	78.81	±	8.35	74.86	±	13.87	0.87	0.39	
REM (%)	21.19	±	8.35	25.14	±	13.87	-0.87	0.39	
REM Efficiency	83.01	±	17.76	95.84	±	4.86	-2.21	0.04	*
NREM in REM (min)	3.46	±	4.33	1.05	±	1.52	1.68	0.11	
Wake in REM (min)	1.29	±	4.24	0.15	±	0.34	0.84	0.41	
REM period (min)	21.61	±	12.24	21.60	±	9.36	0.00	1.00	
# REM fragments	3.86	±	3.08	2.70	±	1.57	1.09	0.29	
Sleep Latency (min)	10.54	±	6.92	12.40	±	12.56	-0.47	0.64	
NR1 latency (min)	10.75	±	6.22	11.35	±	11.30	-0.17	0.87	
NR2 latency (min)	19.50	±	7.36	18.65	±	15.58	0.18	0.86	
NR3 latency (min)	41.82	±	19.68	31.14	±	15.06	1.22	0.24	
REM latency (min)	40.39	±	36.30	39.50	±	24.15	0.07	0.95	

Values presented as mean ± standard deviation. * Values significantly differ $P < 0.05$. TST, total sleep time; NREM, nonrapid eye movement; NR1, NREM stage 1; NR2, NREM stage 2; NR3, NREM stage 3; REM, rapid eye movement.

Associational Breadth

Three CTL participants who did not sleep well were excluded from the sleep-dependent analyses (Priming Effect) but included in the Associational Breadth analyses. One CTL participant did not sleep well and did not return for the 1 week follow-up and was thus excluded from all analyses. Thus, a total of 13 CTL participants and 14 NM participants were included in

Associational Breadth analyses, and 10 CTL and 14 NM participants were including in Priming Effect analyses. See Table 2 for means on all task types and groups.

Table 2. Scores on the associational breadth task for NM and CTL groups.

Table 2. Scores on the associational breadth task for NM and CTL groups on all task types.

		NM			CTL		
Associational Breadth	N	14			13		
Test	Negative	0.86	±	0.17	0.69	±	0.21
	Positive	0.78	±	0.18	0.63	±	0.18
ReTest	Negative	0.86	±	0.14	0.69	±	0.21
	Positive	0.80	±	0.17	0.58	±	0.16
Priming Effect Tasks	N	14			10		
Primed-Test	Negative	0.77	±	0.18	0.52	±	0.27
	Positive	0.80	±	0.18	0.67	±	0.21
Primed-ReTest	Negative	0.85	±	0.15	0.63	±	0.22
	Positive	0.83	±	0.21	0.57	±	0.14
NonPrimed	Negative	0.89	±	0.15	0.65	±	0.18
	Positive	0.76	±	0.17	0.57	±	0.16

Values presented as mean ± standard deviation.

A 2 group (CTL, NM) x 2 cue-type (Negative, Positive) x 2 time-point (Test, ReTest) ANOVA for AB did not reveal a 3-way interaction effect ($F(1, 25)=0.35$, $p=0.56$). There was a significant effect for group ($F(1,25)=17.91$, $p=0.0003$) showing that the NM group had significantly higher AB scores at both baseline and retest. There was also a significant effect for cue-type ($F(1,25)=10.06$, $p=0.004$), revealing that negative AB scores were higher than positive AB scores. There was no main effect for time-point, nor any other 2-way interactions (all $p > 0.64$).

Post-hoc independent samples t-test comparisons revealed that the NM group had higher scores than did the CTL group on both negative ($t(25)=2.22$, $p=0.04$) and positive AB ($t(25)=2.09$, $p<0.05$); as well as higher scores than the CTL group on both negative ($t=2.37$,

p=0.03) and positive AB at ReTest (t(25)=3.27, p=0.003; see Table 2 for means and Figure 2 for comparisons). Within group dependent t-tests did not reveal any significant differences between variables in the CTL group (all $p \geq 0.10$) or the NM group (all $p > 0.20$).

Figure 2. Mean Associational Breadth Scores for NM and CTL groups.

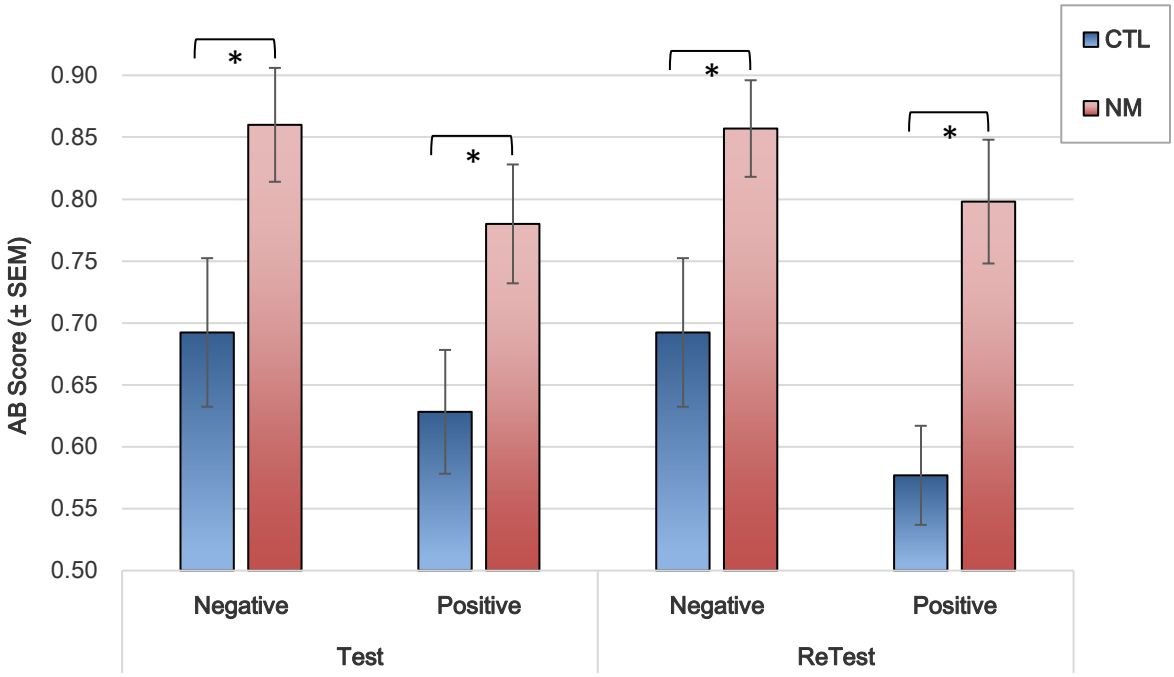


Figure 2. Mean (+/- SEM) Associational Breadth (AB) score for both groups. The NM group had significantly higher scores for both negative and positive cue-words, at both Test and ReTest.
*Values significantly different at P < 0.05.

Priming Effect

A 2 group (CTL, NM) x 2 cue-type (Negative, Positive) x 2 time-point (Test, ReTest) ANOVA for Priming Effect revealed a marginal 3-way interaction effect (F(1,22)=2.68, p=0.12), a significant main effect for cue-type (F(1,22)=8.04, p<0.01), with positive cue-words producing higher AB scores than negative cue-words, and a significant 2-way interaction between cue-type and time-point (F(1,22)=5.21, p=0.03; see Figure 3). These effects were clarified by post-hoc within group dependent samples t-tests which revealed that, for the CTL group, the positive Priming Effect was significantly higher than the negative Priming Effect on the first test (t(18)=3.10, p=0.01), but equal to it at ReTest (t(18)=0.14, p=0.89). Further, the

positive Priming Effect was significantly higher at Test than at ReTest (t(18)=2.32, p=0.30), and the negative Priming Effect tended to be lower at Test than at ReTest (t(18)=-1.79, p=0.09). For the NM group, the positive Priming Effect was also higher than the negative Priming Effect at Test (t(26)=2.41, p=0.03) but in this group the effect was maintained at ReTest (t(26)=2.35, p=0.04). The positive and negative Priming Effects did not differ between Test and ReTest (both p>0.20; see Figure 3).

Figure 3. Mean Priming Effects for NM and CTL groups.

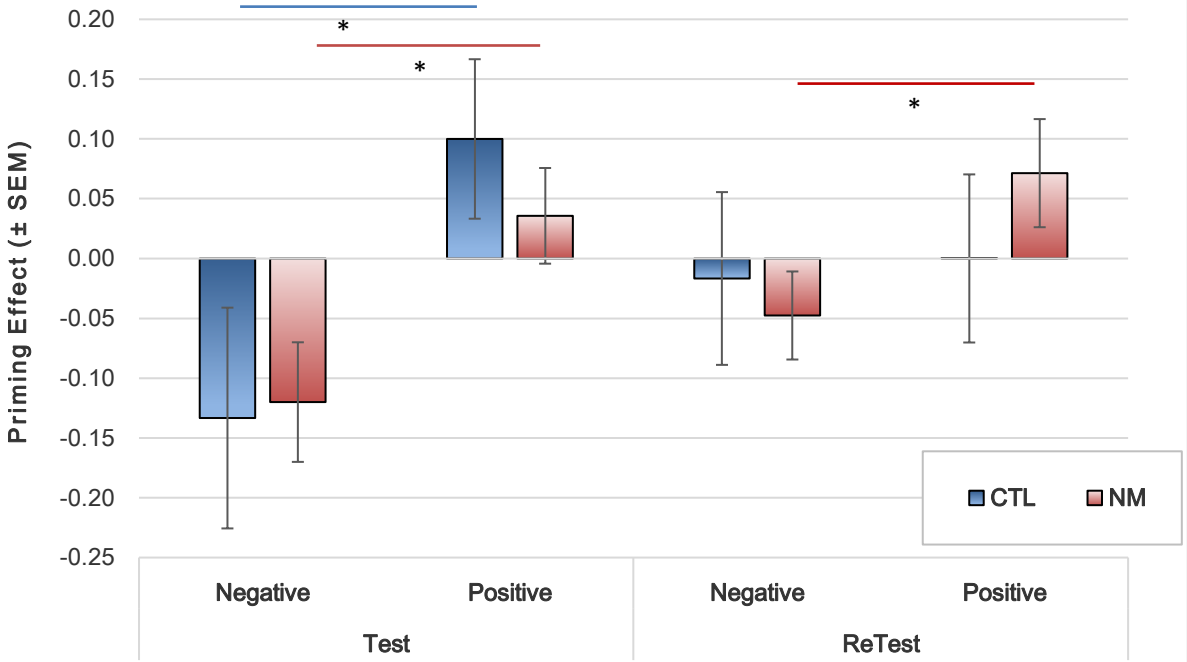


Figure 3. Mean (+/- SEM) Priming Effects for positive and negative word-cues. Both groups showed a significant Priming Effect for positive compared to negative cue-types at Test, but did not differ from each other at ReTest. Only the NM group maintained a significant Priming Effect at ReTest.
* Values differ significantly at P < 0.05.

Associational Breadth Reaction Time

Reaction Times (RT) are presented in seconds as the average time taken by subjects to type all three response words to negative and positive cue-words. One CTL subject who allowed the time meter to run out for all task conditions (despite instructions to respond as quickly as possible) was excluded from analyses. Table 3 displays mean RTs for all task types and groups.

Table 3. Reaction times on the associational breadth task for NM and CTL groups.

Table 3. Reaction times on the associational breadth task for NM and CTL groups.							
		NM			CTL		
Associational Breadth Reaction Time	N	14			12		
Test	Negative	13.82	±	6.88	15.42	±	8.60
	Positive	14.15	±	7.79	13.18	±	4.25
ReTest	Negative	14.30	±	6.69	12.14	±	3.29
	Positive	13.52	±	5.42	13.89	±	5.91
Priming Effect Reaction Time	N	14			9		
Primed-Test	Negative	16.67	±	6.06	16.25	±	6.11
	Positive	14.36	±	6.86	14.25	±	6.24
Primed-ReTest	Negative	17.19	±	6.27	13.09	±	4.92
	Positive	15.96	±	4.75	12.34	±	4.69
NonPrimed	Negative	15.34	±	5.46	11.62	±	3.62
	Positive	14.85	±	6.62	14.50	±	6.10
Values presented as mean ± standard deviation.							

A 2 group (CTL, NM) x 2 cue-type (Negative, Positive) x 2 time-point (Test, ReTest) ANOVA for RT did not reveal a significant 3-way interaction effect ($F(1, 24)=1.35=92$, $p=0.18$). No other main effects or two-way interactions were significant (all $p>0.54$). Post hoc t-tests revealed no between or within group differences (all $p >0.22$).

Priming Effect Reaction Time

Reaction times for the Priming Effect were calculated as for the Priming Effect scores, i.e., Primed RT - NonPrimed RT at both Test and ReTest. A 2 group (CTL, NM) x 2 cue-type (Negative, Positive) x 2 time-point (Test, ReTest) ANOVA for Priming Effect RT did not reveal a significant 3-way interaction effect ($F(1,21)=0.07$, $p=0.79$) and no significant effect for group ($F(1,21)=0.34$, $p=0.57$). However, it did reveal a significant main effect for cue-type ($F(1,21)=6.28$, $p=0.02$), such that positive Priming Effect RTs were faster than negative Priming

Effect RTs. Cue-type interacted only marginally with group ($F(1,21)=2.44$, $p=0.13$); t-test comparisons showed this to be due mainly to the CTL group, who had faster RTs for positive than for negative cue-types ($F(1,21)=6.79$, $p=0.02$) whereas the NM group had similar RTs for the two cue-types ($F(1,21)=0.57$, $p=0.46$; Figure 4).

There was also a trend for a time-point main effect ($F(1,21)=3.28$, $p=0.08$), with RTs decreasing from Test to ReTest. Again, although the time-point X group interaction was not significant ($F(1,21)=1.88$, $p=0.18$), t-test comparisons revealed the trend to be due to the CTL group, who showed faster RTs at ReTest than at Test ($F(1,21)=4.16$, $p=0.05$) whereas the NM group showed no such improvement ($F(1,21)=0.12$, $p=0.73$).

Figure 4. Mean Priming Effect RTs for NM and CTL groups.

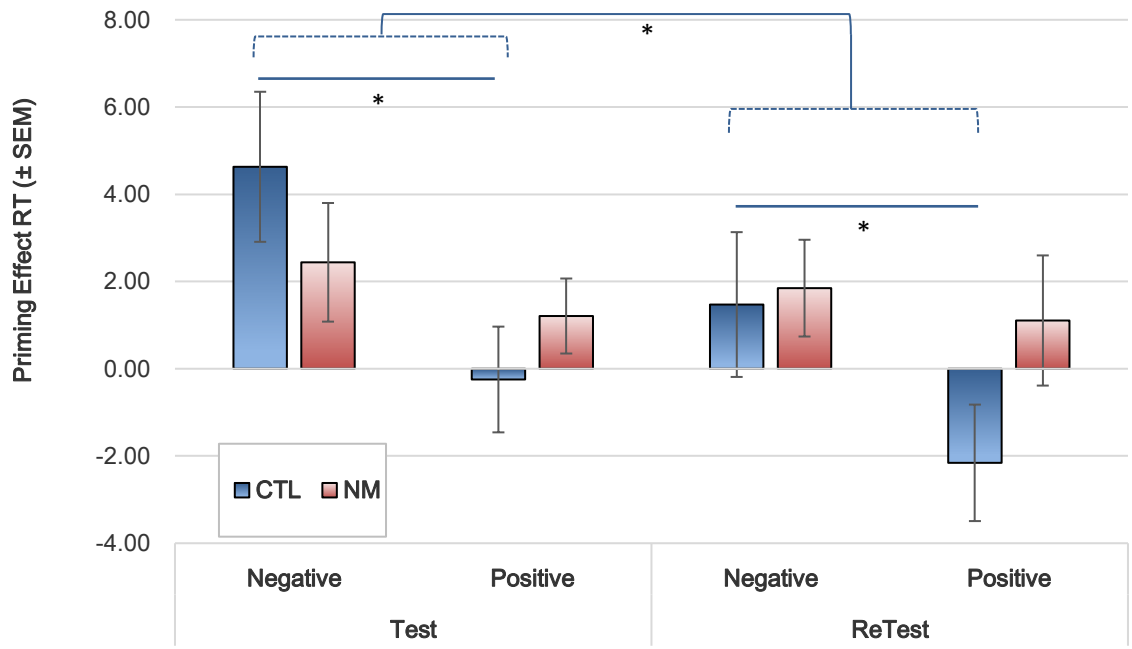


Figure 4. Mean (+/- SD) Priming Effect RTs for positive and negative cue-types. The CTL group showed significantly faster RTs for positive than for negative cue-words at both Test and ReTest, with RTs at ReTest being significantly lower than those at Test. These differences did not obtain for the NM group.
*Values differ significantly at $P \leq 0.05$.

Discussion

Although the provisional hypotheses that NM participants would demonstrate more restricted access to semantic emotional networks both in the form of lower AB task scores and longer RTs were not supported, findings nonetheless reveal telling differences between NM and CTL groups. First, frequent NM sufferers were found to give more unusual responses on the AB task than did CTL participants. They had uniformly higher AB task scores, as indicated by higher scores on both the initial task and the ReTest given one week later, and higher scores in response to both positive and negative cue-words. That this difference was so ubiquitous suggests that it may constitute a consistent trait associated with NM pathology. Further, the fact that no differences were found between groups in reaction times suggests that the NM participants' elevated associative breadth scores were not due to them spending more time searching their associative nets for more remote associations; rather, the differences were likely due to automatic or habitual differences in associative access. These findings agree with the literature suggesting that NM participants benefit from fluid and broad associational abilities, which could promote artistic talent and creative thinking.

Second, NM participants showed immediate REM-dependent changes in associational breadth that were similar to those of CTL participants, being relatively broadened in response to positive cue-words and restricted in response to negative cue-words when tested immediately after their naps. This finding replicates and expands upon our prior finding of a selective positive Priming Effect for healthy college students after a morning nap (Carr & Nielsen, 2015). However, at 1-week ReTest, the NM group showed an enduring Priming Effect that had disappeared in the CTL group. Concurrently, the NM group failed to show an improvement in RTs at ReTest that was seen in the CTL group. It is possible that, for the CTL group, initial REM-dependent changes in associative access dissipated as the emotional cue-words became either fully integrated into memory or fully stripped of their affective charge over time, and one week later the cue-words benefited from strengthened consolidation and faster speed of access (Walker & van Der Helm, 2009). For the NM group, however, the initial REM-dependent changes in associative access did not dissipate, possibly because the cue-words were not fully integrated into memory or their affective charge was not down-scaled over the 1-week delay. In either case, speed of accessing the words did not improve.

The differential influence of positive and negative emotions on associational access during waking state tasks is well-established. For example, induction of positive affect leads to the production of more broad semantic associations in the laboratory (Isen et al., 1985); on the other hand, sadness leads to more constrained and specific item processing (Storbeck & Clore, 2005). Our findings provide further validation of these effects for priming stimuli and for processes linked to sleep. In particular, our priming task produced, as predicted, evidence of restricted associational breadth in response to negative stimuli and increased associational breadth in response to positive stimuli. These consistent findings not only further validate the notion of affect-mediated semantic network access, but they support our AB priming task as a valid measure of this differential effect.

On the other hand, our findings for the AB task without priming did not support an affect-mediated access effect; there was greater associational breadth in response to negative than to positive cue-words in both the AB task prior to sleep and at 1 week ReTest. This contrasts with the clear-cut differences for positive and negative stimuli in the AB priming task. The inconsistency may be due to a difference in processing modes for the baseline and priming tasks. Specifically, relatively automatic processing modes are mediated directly by emotional arousal, whereas controlled processing modes are mediated more by emotional valence (Straube, Sauer, & Miltner, 2011). Our baseline conditions may have triggered an automatic processing mode sensitive to arousal, as suggested by our findings that reaction times did not differ across groups for the baseline AB tasks. In this case, an increased level of arousal, which presumably occurs for NM participants and in response to negative emotions, may covary with increased associational breadth. On the other hand, the priming task may be considered a more controlled cognitive task sensitive to emotion valence, especially considering the effort required for memorizing the priming word list. If so, in the priming condition valence may have exerted a differential (negative restricting, positive broadening) influence on AB. Further, primed reaction times differed by valence, with faster responses occurring for positive than for negative cue-words; this suggests that positive valence correlated with both increased breadth and speed of associative access.

That the effect dissipated over a 1 week delay in the CTL group supports existing proposals that emotional memory integration is dependent on multiple sleep cycles. The “Sleep

to Forget Sleep to Remember" (SFSR) hypothesis suggests that over time, REM sleep promotes strengthened consolidation of emotional memory episodes, while diminishing the emotional charge of such memories (Walker & van Der Helm, 2009). It is possible that the NM group is less efficient at this process, resulting in sustained Priming Effects one week later. There are several potential explanations for this: heightened arousal at encoding may have led to a stronger and more resistant initial Priming Effect; lower REM efficiency could delay full integration; the experience of nightmares during the 1 week delay could interfere with integration. In any case, such results imply that NM sufferers may endure distress and altered emotional cognition for a longer period of time after an emotional event, such as a trauma or adverse experience, a notion which corroborates existing findings of a correlation between prior history of trauma or abuse and nightmare frequency (Agargun et al., 2003; Csoka, Simor, Szabo, Kopp, & Bódizs, 2011).

In sum, findings support the notion that NM sufferers have altered emotional cognition. In waking, they display uncommon emotional associations, corresponding with anecdotal reports of heightened creativity and artistic expression. Following an initial REM nap, they show an emotion-word Priming Effect similar to that of CTLs, which was constricting for negative cue-words and broadening for positive cue-words. However, one week later, the NM sufferers continued to show this Priming Effect robustly whereas the CTL group did not. This may mean that NM sufferers need more time to fully integrate emotional experiences into memory networks. Overall, results reinforce the paradoxical picture of the NM sufferer as an individual who may benefit from an associational capacity that facilitates creative pursuits, while concurrently suffering from inadequate emotional memory integration and all the mental health consequences this may entail.

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2.4 Fourth Article

Intensified daydreams and nap dreams in frequent nightmare sufferers

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Elizaveta Solomonova: contributed to study design and data collection

Tyna Paquette: contributed to study design and recruitment

Tore Nielsen: contributed to study design, analysis and interpretation, article writing

Abstract:

Introduction: Nightmares (NM) are characterized by intense negative emotion. However, research suggests that frequent nightmare sufferers also have heightened dream vividness and greater inclinations to fantasy and dream-like daydreams. We assessed the daydreams and nap dreams of NM participants to determine whether they have more vivid imagery across sleep/wake states, especially with respect to affect, sensation, and bizarre imagery attributes.

Methods: NM and control (CTL) participants completed a daydream procedure followed by a nap targeted to contain 80 minutes total sleep time and an awakening 10 minutes into REM sleep. Following reports of both daydreams and nap dreams, participants completed an imagery attribute questionnaire regarding four factors: negativity, positivity, body sensation and bizarreness.

Results: The NM group had elevated positivity, body sensation and bizarreness ratings for daydreams compared to the CTL group, but did not differ for negativity ratings. NM participants also had elevated body sensation ratings for nap dreams, but did not differ for negativity, positivity or bizarreness.

Discussion: While nightmares themselves are characterized by negative affect, NM sufferers nonetheless have higher than normal positivity, sensation and bizarreness in their daydreams and to a lesser extent in their nap dreams. This effect may reflect some change in the affective structure of imagery among nightmare sufferers (e.g., altered experiences of bodily arousal), the differential influence of circadian factors on the two groups, or the fact that sleeping in the laboratory tends to suppress nightmares.

Keywords: nightmares, emotion, REM sleep, dreaming, daydreaming, naps

Introduction

The nightmare is an intensely unpleasant dream occurring in REM sleep and often awakening the dreamer (American Psychiatric Association, 2013). A nightmare's content typically deals with threat and is characterized by fear or other negative emotions such as sadness or anger. While occasional nightmares are nearly ubiquitous, frequent nightmares—occurring about once per week or more—affect 4-6% of the population (American Psychiatric Association, 2013; Levin & Nielsen, 2009). Idiopathic nightmares (iNMs) have no known cause and, when they occur only occasionally, appear to be a normal and even adaptive response to ongoing stress or current concerns. However, frequent nightmares are usually associated with persistent waking distress and lower psychological well-being (Zadra & Donderi, 2000). Further, individuals experiencing frequent nightmares are more likely to suffer from anxiety, depression, and other affective difficulties, such as alexithymia, and are at higher risk of suicide (Levin & Nielsen, 2009). Although many nightmare sufferers do not seek treatment and often report that they do not consider their nightmares to be a problem (Schredl, 2013).

In fact, nightmare sufferers may possess an enriched dreaming life of which nightmares are only a part of this. For example, frequent nightmare sufferers have higher than average recall of non-nightmare dreams, and report heightened affect and vividness in these dreams (Levin, 1994). Further, while nightmares may well be intensified dreams marked by negative affect, frequent nightmare sufferers are also more likely to experience intensified dreams marked by positive affect, including archetypal or lucid dreams (Spadafora & Hunt, 1990). All these findings suggest that nightmare sufferers may be characterized by an intensification of dreaming processes which may be expressed either positively or negatively depending on factors such as current levels of stress or different personality characteristics (Nielsen, 2011a).

Such an intensification of the dreaming process may also have counterparts in waking cognition, particularly waking daydreams. Models relating dreaming to waking fantasy and 'mind-wandering' suggest that a continuum of cognitive activity ranges from focused thought on one extreme, through daytime mind-wandering (ie, daydreaming, fantasy, imagination), to dreaming on the other extreme (Domhoff & Fox, 2015; Fox, Nijeboer, Solomonova, Domhoff, & Christoff, 2013; Hartmann, 2007; Klinger, 1971). In other words, dreaming is considered to be an intensified form of mind-wandering (Domhoff & Fox, 2015). Accordingly, individuals

who frequently experience nightmares and other forms of intensified dreams should also be prone to intensified daydreams. Some research supports this notion, including findings that attributes of waking fantasies are similar to those of REM dreams, particularly in regards to their affective tone (Kramer, Roth, Arand, & Bonnet, 1981; Starker, 1977). Also, daydreaming styles are reflected in elements of nighttime dreams; for example, a daydreaming style characterized by anxiety and distractibility is correlated with nighttime dreams that are highly bizarre and emotional. Further, the personality construct of boundary thinness, or a tendency to be more sensitive to emotions and sensations, is correlated both with nightmare frequency and with a propensity to experience immersive and bizarre daydreams (Hartmann, 2007). Nonetheless, dreams, particularly from REM sleep, are typically more bizarre than daydreams (Carr & Nielsen, 2015a) and contain more negative affect, whereas daydreams and mind-wandering have been associated with higher levels of positive affect (Fox et al., 2013).

Despite these findings, controlled laboratory comparisons of the dreams and daydreams of frequent nightmare sufferers have not been conducted. Moreover, the retrospective studies that have assessed both dreams and daydreams have not adequately defined the daydreaming state. Our recent study using a novel method of collecting morning nap dreams and daydreams did control many of these factors, thus providing a more consistent method of mentation sampling (Carr & Nielsen, 2015a). For example, participants reported their daydreams and dreams within the same environment (the laboratory bedroom), near the same time of day, and with clear and repeated instructions for reporting. Further, our finding of high dream recall rates from morning REM sleep naps (96%) is higher than the average for nocturnal sleep studies (80%; see Nielsen, 2011b for review) and more similar to that of late night REM sleep awakenings (95%; e.g., Cicogna, Natale, Occhionero, & Bosinelli, 1998). This, and the fact that nightmares and other intensified dreams are more likely to occur during later REM periods and closer to the circadian peak of REM sleep propensity suggests that our morning nap protocol is particularly well-suited for the study of nightmare sufferers (Wamsley, Hirota, Tucker, Smith, & Antrobus, 2007).

Objectives:

We compared waking daydream and REM dream reports collected within a morning nap protocol for both nightmare (NM) sufferers and controls (CTL), using participants' ratings of

levels of affect, body sensation, and bizarreness in these reports. We predicted that NM sufferers would have more intensified waking daydream and nap dreams, as indicated by greater positively and negatively valenced affect and body sensations, and bizarre attributes. We also expected to replicate findings that REM dreams are more intense than waking daydreams, for both groups.

Materials and Methods

Participants

Twenty-eight participants (20 female) between the ages of 18 and 35 (Mage=23.3±3.43) were recruited using advertisements and posters. NM participants (N=14) recalled at least 2 nightmares per week for the past 6 months whereas CTL participants (N=14) recalled at least 2 dreams per week and less than 1 nightmare per month for the past 5 years. Potential participants were screened for self-reported sleep, neurological, or psychological disorders, or the use of certain medications. All participants signed informed consent forms which had been approved by the ethics committee of the Hôpital du Sacré-Coeur de Montréal.

Procedures

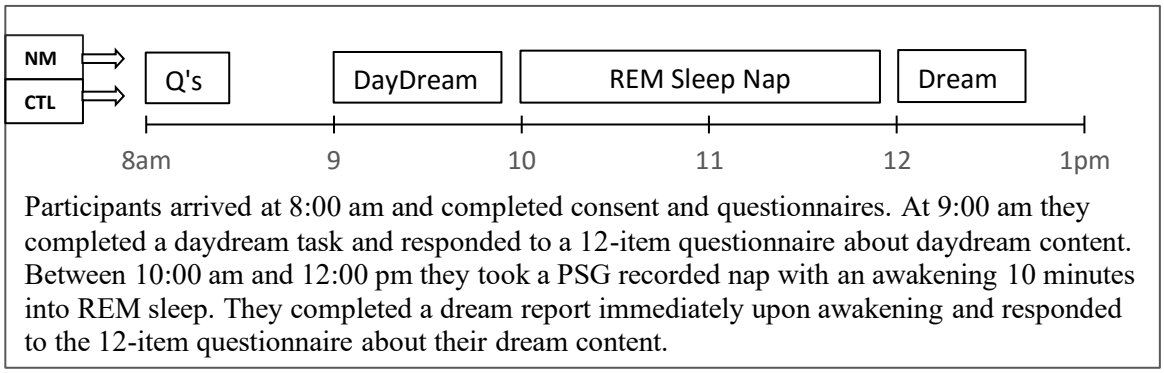
Participants arrived at 8:00 am, completed the informed consent form and filled out a series of questionnaires that took approximately 30 minutes.

At 9:00 am participants were given instructions for a brief word association task that they would complete both before and 1 hour after a morning nap (results reported elsewhere). They then completed the daydream procedure and responded to a 12-item questionnaire about their daydream content.

Following this, a technician attached an electrode montage for polysomnography and between 10:00 a.m. and 12:00 p.m. participants were given a 2-hour opportunity to nap. A different technician with substantial experience in sleep staging awakened them 10 minutes into REM sleep provided that a minimum of 50 minutes and a maximum of 2 hours of total sleep time had elapsed.

Upon awakening, participants immediately typed out their dream report and then completed a 10 item questionnaire regarding dream content (see Figure 1).

Figure 1. Study Design



Participants arrived at 8:00 am and completed consent and questionnaires. At 9:00 am they completed a daydream task and responded to a 12-item questionnaire about daydream content. Between 10:00 am and 12:00 pm they took a PSG recorded nap with an awakening 10 minutes into REM sleep. They completed a dream report immediately upon awakening and responded to the 12-item questionnaire about their dream content.

Questionnaires: A packet of questionnaires was administered to assess participant characteristics, including recall frequency of dreams, bad dreams (without awakening), and nightmares (with awakening), anxiety levels (State Trait Anxiety Inventory; Spielberger, Gorsuch, & Lushene, 1970), depression (Beck Depression Inventory; Beck, Steer, & Brown, 1996), nightmare distress (Nightmare Distress Questionnaire; Belicki, 1992), and alexithymia (Toronto Alexithymia Scale; Taylor, Bagby, & Parker, 2010).

Polysomnography: Participants slept in bedrooms with continuous audio-visual surveillance and a 2-way intercom. They were recorded with an electrode montage of 6 standard 10-20 EEG channels (F3, F4, C3, C4, O1, O2) referenced to A1, 4 EOG channels (2 vertical, 2 horizontal), 4 EMG channels (chin, corrugator), and 3 EKG channels. Biosignals were recorded using a Grass M15 Neurodata Acquisition Systems (-6dB filters with cut-offs at 0.30 and 100 Hz) and archived under the control of Harmonie 5.4 software (Natus Medical Inc., Montreal, Canada). PSG tracings were visually monitored during the nap and participants awakened 10 minutes into REM sleep after a minimum of 50 minutes and a maximum of 2 hours sleep had elapsed. Tracings were later scored according to current AASM standards (Berry et al., 2012) and standard sleep variables (REM min, %REM, NREM min, %NREM, TST) were calculated by in-house software (detailed results are reported in Carr, Blanchette-Carrière, Marquis, Ting, & Nielsen, submitted).

Daydream and Dream Report Collection: Participants were given a set of instructions at the beginning of the experiment informing them of the daydream and nap dream report procedures. The instructions were presented on a computer screen that swiveled out from beside the bed:

> *At the beginning of the experiment you will be asked to sit with your eyes closed for three minutes and to think or daydream about anything. After three minutes you will hear a beep, at which point you can open your eyes and immediately fill in a 'mentation report' about any daydreams or thoughts you had while your eyes were closed. You will then answer some questions about your daydream.*

This procedure will be exactly the same upon awakening from your nap, when you will be asked to immediately fill in a dream report and answer some questions about your dream.

Daydream Report: Prior to the daydream report, participants received specific instructions to sit in a relaxed position on the bed for three minutes, keeping their eyes closed while their mind was free to think or daydream about anything. If participants opened their eyes during this session, the screen continued to display instructions to keep their eyes closed until the beep.

Following the three minutes, an 80 dB 500-hz tone was sounded and participants were instructed to immediately type in a report of whatever was going through their mind prior to the tone, with a reminder to include as much detail as possible ("Please describe what was going through your mind prior to the beep. Include details on characters, settings, objects, actions and emotions. If you have no recall, type -no recall-"). They were given unlimited time to write the report.

Following this, participants completed a 12-item questionnaire using 1-9 response scales about specific imagery attributes such as negative and positive emotion, and bizarreness.

Dream Report: Participants were awakened from REM sleep with the same non-stressful, 80 dB 500-Hz tone that had been used for the daydream procedure and were given the same instructions to immediately type in a report of whatever was going through their mind prior to the beep. They were given unlimited time to type out their dream report including as

much detail as possible, prior to responding to the same 12-item questionnaire about specific imagery attributes.

Daydream and Dream Attributes: The imagery attributes questionnaire consisted of 12 items which were all rated with 1-9 scales with 1 being very little and 9 being extremely high amounts of the designated attribute. The first item, about image clarity, included an optional response of 0 to indicate no recall ("How clearly can you recall your experience?"). All other items used only the 1-9 scales. There were three items about negative imagery content ("What was the extent of negative emotion intensity/negative emotion frequency/fear in this experience?"), two items about positive imagery content ("What was the extent of positive emotion intensity/positive emotion frequency in this experience?"), two items about body sensations ("What was the extent of positive/negative body sensations in this experience?") and four items about bizarre dream content ("To what extent was this experience unfamiliar/bizarre/discontinuous/confusing?"). Attribute ratings were averaged within categories to give a single score each for negativity, positivity, body sensation, and bizarre content, for both daydream and dream conditions. High values on any of these average scores was taken to indicate intensification of the imagery for that particular attribute.

Statistical Analyses

Analyses tested if NM sufferers had more intensified dream and daydream experiences in all four attribute categories (negativity, positivity, sensations, bizarre), and if dreams were more intense than daydreams, particularly in negative and bizarre attribute categories. A 2 group (NM, CTL) x 2 condition (daydream, dream) x 4 attribute (negativity, positivity, sensations, bizarre) ANOVA was conducted to test for the main effect of group, a main effect of condition, and an interaction of condition and attribute. A corrected p-value of 0.007 was used to control for the multiple comparisons of the design (a 2x2x4 ANOVA tests for 7 effects, thus the traditional significance level of 0.05 / 7 tests = 0.007). Exploratory t-test analyses were conducted to compare the specific attribute categories by group.

Results

Questionnaires

Table 1. Demographics and questionnaire measures for NM and CTL groups

Table 1. Demographics and questionnaire measures for Nightmare and Control groups

	NM	CTL	t	p	
N	14	14			
Sex Ratio	10 : 4	10 : 4			
Age	23.29 ± 3.29	22.71 ± 3.67	0.43	0.67	
D/wk	6.75 ± 3.24	4.32 ± 2.52	2.21	**0.04**	*
BD/wk	2.79 ± 1.42	0.29 ± 0.47	6.24	**0.00**	**
NM/wk	1.96 ± 1.37	0.00 ± 0.00	5.38	**0.00**	**
ASTA-State	36.50 ± 10.59	31.71 ± 6.13	1.46	0.16	
ASTA-Trait	44.43 ± 11.57	38.64 ± 8.79	1.49	0.15	
BDI	14.71 ± 12.98	6.71 ± 6.70	2.05	0.05	†
NM-Distress	33.29 ± 8.20	24.71 ± 6.01	3.15	**0.00**	**
TAS	48.14 ± 10.76	43.85 ± 7.07	1.22	0.24	
DIF	17.43 ± 5.37	13.69 ± 3.12	2.19	**0.04**	*
DDF	12.86 ± 4.44	12.23 ± 2.74	0.44	0.67	
EOT	17.86 ± 4.57	17.92 ± 3.64	-0.04	0.97	

Values presented as mean ± standard deviation. *P < 0.05, **P < 0.005 †P < 0.06. D/wk, dreams per week; BD/wk, bad dreams per week; NM/wk, nightmares per week; STAI, State Trait Anxiety Inventory; BDI, Beck Depression Inventory; NM-Distress, Nightmare Distress Questionnaire; DIF, difficulty identifying feelings; DDF, difficulty describing feelings; EOT, externally oriented thinking; TAS, Toronto Alexithymia Scale.

Participants did not differ in Age ($t(26)=-0.43$, $p>0.67$). NM participants recalled significantly more dreams ($t(26)=2.21$, $p=0.04$), bad dreams ($t(26)=6.24$, $p<0.001$), and nightmares per week than did CTL participants ($t(26)=6.24$, $p<0.001$). Groups did not differ in

State or Trait Anxiety measures ($p>0.15$). NM participants tended to score higher on the depression index ($t(26)=2.05$, $p=0.05$); they also had higher Nightmare Distress scores ($t(26)=3.15$, $p<0.005$). NM participants had higher Alexithymia scores for the Difficulty Identifying Feelings subscale ($t(26)=2.19$, $p=0.04$), but not the Difficulty Describing Feelings, Externally Oriented Thinking, or Total Alexithymia Score (all $p>0.24$). Table 1 for means and standard deviations.

Sleep Structure

4 CTL participants were excluded for not sleeping or for awakening well before target time. Groups did not differ in minutes of NREM sleep ($p=0.80$), minutes of REM sleep ($p=0.31$), or TST ($p=0.55$) in the nap. However, the NM group had significantly lower REM efficiency ($t(22)=-2.21$, $p=0.04$). See Table 2 for means.

Table 2. Sleep stage measures for naps of NM and CTL groups.

Table 2. Sleep stage measures for naps of Nightmare and Control groups.

	NM	CTL	t	p
TST	82.11 ± 21.31	88.20 ± 27.86	-0.61	0.55
Sleep Efficiency	91.35 ± 7.99	90.09 ± 12.30	0.31	0.76
NR1 (min)	13.75 ± 6.38	14.60 ± 11.06	-0.24	0.81
NR2 (min)	38.36 ± 18.14	37.10 ± 20.56	0.16	0.88
NR3 (min)	13.14 ± 16.03	16.10 ± 12.08	-0.49	0.63
NREM (min)	65.25 ± 22.24	67.80 ± 27.62	-0.25	0.80
REM (min)	16.86 ± 8.28	20.40 ± 8.10	-1.04	0.31
REM Efficiency	83.01 ± 17.76	95.84 ± 4.86	-2.21	0.04 *
NREM in REM (min)	3.46 ± 4.33	1.05 ± 1.52	1.68	0.11

Values presented as mean ± standard deviation. * Values significantly differ $P < 0.05$. TST, total sleep time; NREM, nonrapid eye movement; NR1, NREM stage 1; NR2, NREM stage 2; NR3, NREM stage 3; REM, rapid eye movement.

Daydream and Dream Measures

2 CTL participants reported no dream recall and were excluded (in addition to 4 CTL participants who did not have REM sleep). Therefore, analyses were conducted with 7 CTL participants. All NM participants (N=14) completed daydream and dream recall tasks successfully and were included in all analyses. Average daydream and nap dream attribute ratings used in the analyses are reported in Table 3.

Table 3. Average daydream and nap dream ratings for NM and CTL groups.

Table 3. Average daydream and nap dream attribute ratings for Nightmare and Control groups.

	NM	CTL
Daydream	N=14	N=7
Negative	2.64 ± 2.04	2.10 ± 1.87
Positive	6.25 ± 2.22	3.29 ± 1.25
Sensation	4.04 ± 1.50	2.14 ± 1.49
Bizarre	2.82 ± 1.44	1.43 ± 0.53
Dream	N=14	N=7
Negative	3.83 ± 2.18	3.76 ± 2.73
Positive	3.36 ± 1.46	2.36 ± 1.31
Sensation	3.71 ± 1.38	1.64 ± 1.11
Bizarre	5.39 ± 1.85	5.50 ± 1.51

Values presented as mean ± standard deviation

Dream and Daydream Comparisons

A 2 group (NM, CTL) x 2 condition (daydream, dream) x 4 attribute type (negativity, positivity, sensations, bizarre) repeated measures ANOVA revealed no significant 3-way interaction ($F(3, 57)=0.64$, $p=0.59$). However, as expected, there was a group effect ($F(1, 19)=13.04$, $p=0.002$) revealing that the NM group had higher daydream attribute ratings overall. There was also, as predicted, an interaction between condition and attribute type ($F(3,$

57)=14.032, p<0.00001), revealing that dreams were specifically more bizarre (t(19)=6.49, p=0.000003), whereas daydreams were specifically more positive (t(19)=-2.92, p=0.008), while the two did not differ in body sensations (t(19)=1.19, p=0.25) or negative affect (t(19)=19.05, p=0.06). The main effects of condition (F(1, 19)=6.64, p=0.02) and attribute type (F(3, 57)=3.49, p=0.02) did not withstand the corrected p-value of 0.007. Interaction effects between condition and group (F(1, 19)=3.98, p=0.06), and attribute type and group (F(3, 57)=2.96, p=0.04) were not significant.

Exploratory t-test comparisons revealed that, within daydreams, the NM group had higher positivity ratings (t(19)=3.25, p=0.004), body sensations (t(19)=2.73, p=0.01), and bizarreness (t(19)=2.45, p=0.02), but did not differ in negativity ratings (t(19)=0.59, p=0.56; see Table 3 and Figure 2). These exploratory analyses were not corrected for multiple comparisons.

Figure 2. Mean daydream attribute ratings for NM and CTL groups.

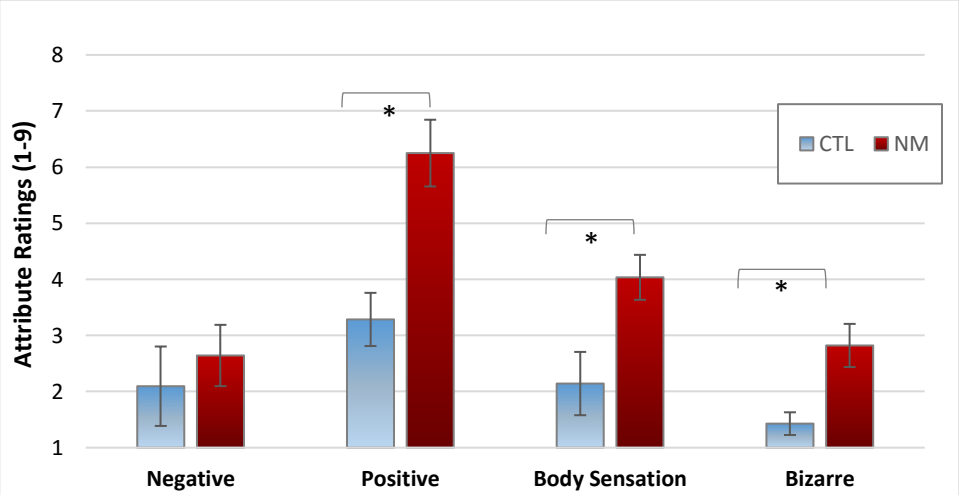


Figure 2. Mean (±SD) daydream attribute ratings. The NM group had significantly higher bizarrenes, and tended to have higher positivity. Positivity was higher than both negativity and bizarreness for both groups.
*P < 0.05. †P = 0.07.

Exploratory analyses comparing the two groups' dream attributes revealed that the NM group had higher body sensations (t(19)=3.44, p=0.003) than the CTL group, but did not differ in positivity (t(19)=1.53, p=0.14) negativity (t(19)=0.07, p=0.95) and bizarreness (t(19)=-0.13, p=0.90) attribute ratings (see Table 3 and Figure 3).

Figure 3. Mean dream attribute ratings for NM and CTL groups.

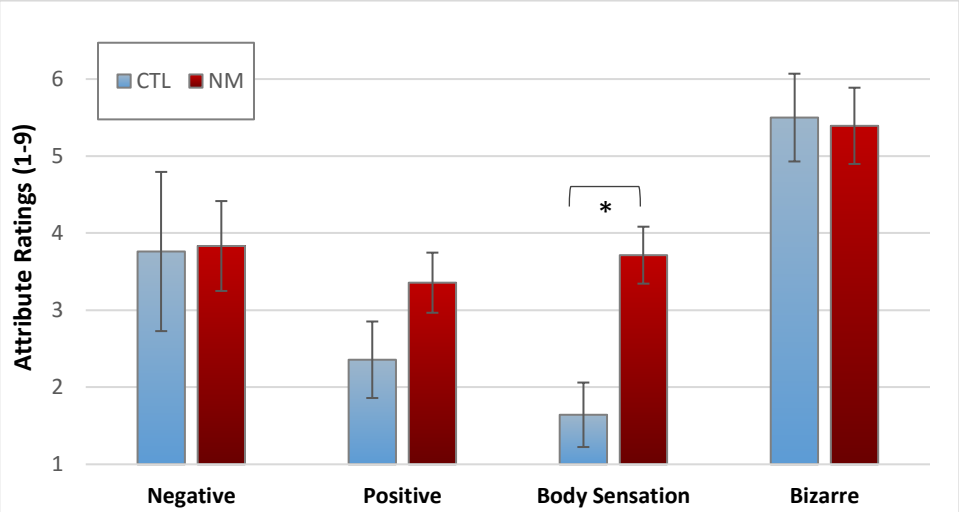


Figure 3. Mean (±SD) nap dream attribute ratings. The NM group had significantly higher positivity than did the CTL group. Bizarreness was higher than negativity or positivity for both groups. *P<0.05.

Discussion

The present results provide partial support for our hypotheses that nightmare sufferers would have more intensified daydreams and nap dreams and suggests some new possibilities for explaining the pathological mechanisms of frequent nightmares. Consistent with our hypothesis, the nightmare group reported higher positivity, body sensation, and bizarreness ratings in their daydreams, but only higher body sensation ratings in their nap dreams. These findings agree with prior research showing that nightmare sufferers have generally intensified dreaming, including more vivid and immersive daydream and nap dream experiences, despite being characterized by the typically negative emotional intensity of their nightmares and their affect distress (Levin & Nielsen, 2007; Spadafora & Hunt, 1990). Indeed, the questionnaire analyses revealed our nightmare group to have certain affective symptomology including higher nightmare-distress and alexithymia (DIF) as well as a tendency towards depression.

Contrary to predictions, however, the nightmare group did not show overall higher negativity in either their nap dreams or daydreams. This finding, in fact, runs counter to our previous findings that nightmare sufferers report more anxiety in dreams recorded in home logs (Nielsen, Paquette, Solomonova, Lara-Carrasco, Colombo, et al., 2010; Nielsen, Paquette,

Solomonova, Lara-Carrasco, Popova, et al., 2010). However, the finding of elevated body sensation ratings in both the dreams and daydreams of nightmare sufferers may well be consistent with our previous finding that nightmare sufferers also rate their home dreams as containing more inhibition/ineffectuality (Nielsen, Paquette, Solomonova, Lara-Carrasco, Popova, et al., 2010). Our present findings add to this the observation that positive and negative body sensations are elevated in the daydreams and nap dreams of nightmare sufferers. Together, the findings are therefore consistent with the possibility that even the non-nightmare dreams of nightmare sufferers, and possibly also their daydreams, are marked by chronic depiction of more salient or more vivid body sensations, which may contribute to both negative dream imagery, e.g., bodily inhibition/ineffectuality, or positive imagery, e.g., unrestrained movement or sensual pleasure. Such forms of affective body imagery may heighten emotional experiences, including, in the first case, negative emotions such as anxiety or fear (nightmares), but also, in the second case, more intense positive emotions such as freedom and euphoria (flying dreams, erotic dreams).

There is yet no definitive explanation for the present, partially unexpected, pattern of findings. One possibility is that dream emotions change across the night because of circadian or sleep-dependent factors (Nielsen, 2011b; Wamsley et al., 2007). As morning nap dreams occur closer to the apex of the circadian REM sleep propensity curve, the emotional content of accompanying dreams relative to nighttime dreams may also differ at this time. Further, some authors have demonstrated that emotional late-night REM dreams may be less negative than early-night dreams, particularly in patients dealing with depression (Cartwright, Young, Mercer, & Bears, 1998). Such an affective pattern might also occur for nightmare sufferers, with even less negativity occurring during morning naps. Further assessments of imagery emotions assessed at different times of the day and night are needed to determine how daydream and dream emotions are modulated around the clock among nightmare sufferers and healthy controls.

A second possibility is that some aspect of the current methodology interfered with the depiction of negative affect that we expected to find in daydreams and nap dreams. It is an often cited observation that nightmare sufferers, like other parasomnia sufferers, do not exhibit their symptoms when sleeping in the laboratory (Fisher, Byrne, Edwards, & Kahn, 1970; Woodward,

Arsenault, Murray, & Bliwise, 2000). Accordingly, none of our participants reported full-blown nightmares during their laboratory naps. This "nightmare suppression" effect is still unexplained, but some have speculated that nightmare sufferers feel more secure sleeping under the watchful eye of professional sleep researchers (LaBerge & Rheingold, 1990).

Besides emotional content, another finding that is partially consistent with predictions is that nightmare sufferers had higher bizarreness ratings in their daydreams than did CTL participants. The difference for daydreams might be considered consistent with previous findings that nightmare sufferers are higher in fantasy proneness and creative aptitude (Hartmann, Russ, Van der Kolk, Falke, & Oldfield, 1981; Levin & Fireman, 2001). The result also mirrors our recent finding that nightmare sufferers have higher than normal scores on an emotion-cued associational breadth task, since associational breadth may reflect a broader than usual spread of activation in semantic networks (Carr & Nielsen, 2015b), and imagery bizarreness in both dreams and daydreams has been interpreted to reflect heightened associative memory activation (Carr et al., 2016; Carr & Nielsen, 2015b; Stickgold, Scott, Rittenhouse, & Hobson, 1999). The finding of high bizarreness is also consistent with the concurrent high levels of positivity in the daydreams of nightmare sufferers, given that access to semantic networks has been shown to be increased by positive mood in waking state tasks; for example, positive emotion leads to more unusual word associations, along with improved performance on a Remote Associate's Task (Isen, Daubman, & Nowicki, 1987; Isen, Johnson, Mertz, & Robinson, 1985). Thus, positivity during daydreams may have facilitated associative spread, further enhancing imagery bizarreness (Garland et al., 2010). As expected, both groups had higher ratings of bizarreness in their dreams as compared with their daydreams, which fits with current models of dreaming as being a hyper-associative creation of REM sleep.

While the groups did not differ in emotion or bizarreness ratings of their dreams, it might also be argued that, relative to their history of rich dream experiences, the nightmare participants did not find their laboratory dreams to be especially emotional or bizarre, even though they may have been relatively moreso than CTL participants' dreams by objective standards. We, in fact, found that some of the dream reports from nightmare participants did appear more emotional and bizarre than those of controls, even though they were not rated as such (see Table 4).

Consistent with this reasoning, one study showed that patients with schizophrenia spontaneously rated their dream reports as being less bizarre than did blind judges (Lusignan et al., 2009).

Table 4. Examples of affect, sensation and bizarreness in daydream and nap dream reports from NM sufferers and CTLs.

Table 4. Examples of emotions and bizarreness in daydream and nap dream reports from NM sufferers and CTLs

NM	CTL	
Daydreams		Comments:
…I briefly imagined small people exploring my organs... Prior to this, I imagined a ship sailing in a fresh water lake… I could feel and smell the wind. It was generally peaceful.	I started thinking about a friend, to whom I loaned 100$ very recently…I was imagining myself questioning him angrily later today.	NM daydream is bizarre and positive (peaceful) with many sensations (feel/smell wind); CTL daydreams is angry but the imagery is not bizarre
I was thinking about how fulfilling and beautiful it would be if I gave birth to a plate of chicken wings and a piece of Stilton. The flavours were almost tangible.	I was thinking about a date I`m going on tonight and worrying slightly…but justifying that I do not know this person so it is fairly inconsequential if it doesn't work out	NM daydream is bizarre and sensation-filled (positive-flavours, negative-birth); CTL daydream is worrying but the imagery is not bizarre
Dreams		Comments:
...I found myself outside with all the gear (electrodes) still stuck to my face. The sun was excessively bright…	…MC came in with a lab coat and glasses and the clothes she is wearing today (grey shirt and jeans). She asked about my dream.	NM dream contains more sensations (stuck to face, bright sun) and seems bizarre; CTL dream does not seem bizarre
…I was trying to fall asleep and not doing very well…at one point my bed was in fact outside…with cyclists weaving in circles around my bed...	I had returned to the table [in the lab] to take the electrodes off. Then I went back to the sleep room trying to find my shoes and purse and bag…Felt a little anxious…	NM dream has some negative emotion ("not doing very well") and seems bizarre; CTL dream has some negative emotion but does not seem bizarre

In conclusion, our laboratory findings suggest that nightmare sufferers experience more intensified and vivid imagery in both their waking daydreams and morning nap dreams, particularly expressed as increased body sensation in their daydreams and nap dreams, and more positivity and bizarreness in their daydreams. These findings are in contrast to typical clinical profiles of nightmare sufferers, who are characterized only by their dysphoric symptomology, symptoms which we also found in the form of higher distress, alexithymia and depression scores and higher retrospective estimates of recalling bad dreams and nightmares. Analyses further point to a predominance of bodily-oriented imagery of both positive and negative valence in both daydreams and nap dreams. This partially unexpected pattern of results broadens our view

of nightmare pathology and suggests a number of hypotheses about the pathogenesis of nightmares for future research.

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3. Discussion

3.1 Summary of findings

The first objective of the thesis, examined in Study 1, was to compare associativity and mental imagery attributes in waking, NREM and REM sleep; these objectives required us to establish a protocol and develop a task that would allow for sleep sensitive testing of associative access to emotional memory. Further, the protocol had to allow for consistent assessment of mental imagery across sleep and wake states. The use of a daytime nap allowed the comparison of similar sleep lengths containing NREM sleep only, NREM+REM sleep, and a control Wake group. Our results showed that, using a novel emotional semantic task measuring Associational Breadth (AB), only those subjects with REM sleep had higher scores for stimuli they had studied prior to sleep. This suggests that REM sleep is unique in its capacity to integrate emotional memory traces broadly into the brain's network of semantic associations (article 1). Our assessment of mental imagery measures across sleep/wake states, was also allowed by applying these new procedures. The imagery comparisons showed an interesting pattern of differences between the three groups, with NREM sleep dreams showing the least intense imagery, while both waking daydreams and REM dreams showed heightened levels of emotion, and only REM dreams had heightened levels of bizarreness (article 2). The emotional intensity of REM dreaming mirrors the proposed function of REM sleep in integrating emotional memory traces, while the bizarreness of REM dreams may reflect the broad semantic associations activated during REM sleep.

Our second objective, examined in Study 2, was to compare nightmare and control groups on associativity and mental imagery attributes in waking and REM sleep; these objectives required us to modify our protocol and apply it to a population of frequent nightmare sufferers (NM). Modifications to the protocol included: 1) comparison of baseline AB performance between groups to assess non-experimental differences in emotional semantic access; 2) re-organizing the emotional AB task to assess positive and negative AB separately due to post-hoc assessments suggesting the two cue-types were differently affected by REM sleep; 3) expanding the protocol to include a one week re-test to assess the lasting effects of REM sleep on emotional semantic access.

Our results showed that NM sufferers give more unusual emotional semantic associations than CTL participants at baseline and one week later; this corresponds with anecdotal reports and some published work showing heightened creativity in NM sufferers. However, following REM sleep both groups showed similar sleep-dependent changes in their AB scores, with negative AB becoming restricted and positive AB becoming broadened. One week later, the NM group maintained this altered pattern of responding, while the CTL group returned to baseline AB levels, and increased their speed of task completion (article 3). These results suggest that, in both groups, REM sleep initially functioned to integrate positive memory traces intro broad networks of semantic association, while it inhibited the integration of negative memory traces. This was a novel contribution to sleep literature, even while it conceptually replicated findings from the waking cognition literature showing differential effects of positive and negative emotion cue-words on associational processes. However, that the CTL group AB scores returned to baseline with improved speed one week later, while those of the NM group did not, suggests that nightmares may be associated with impaired integration and regulation of emotional memory traces over the long term.

While we expected NM participants to have intensified mental imagery across all attributes, our comparison of imagery attributes for the groups only partially confirmed this expectation. Specifically, NM participants had heightened bizarreness and positive, but not negative, emotion in their daydreams when compared with those of CTL participants. Further, the NM group had heightened body sensations in both their daydreams and their nap dreams (article 4). These findings mirror the AB results in that the NM group had significantly higher associativity (bizarreness) in wake, but not following REM sleep. The incidence of higher body sensations also parallels clinical findings of physiological hyperarousal in nightmare sufferers, and suggests that this bodily arousal may permeate both waking and sleeping imagery.

The results have strong implications for nightmare pathology. While nightmares are typically characterized only by their dysphoric symptoms, our results suggest a more complete portrait of individuals who also benefit from a large associative capacity and a vivid imagination, even while suffering from impaired regulation of emotional memory over time. These findings will be discussed within a novel *Environmental Sensitivity* framework of nightmares, which proposes that nightmare sufferers are highly sensitive to a range of environmental contexts,

including both negative and positive affective experiences, the consequences of which may at times be beneficial for creativity and empathy, but at other times maladaptive for regulating arousal.

3.2 Study 1

3.2.1 Evidence of emotional memory integration during REM sleep

In Study 1, the words studied prior to sleep (primed words) were presumably "tagged" in short-term memory and subsequently re-activated within the hyper-associative environment of REM sleep (Redondo & Morris, 2011). This reactivation led participants to respond with more broad and unusual word associations when confronted with the primed cue-words after the nap. These results conceptually replicated a prior finding that performance on a Remote Associates Test (RAT), and specifically for RAT cue items that had been primed prior to sleep, is improved following REM sleep, but not following NREM sleep or wake (Cai et al., 2009). Both the RAT task and our AB task presumably rely on broad spreading activation in semantic networks (Topolinski & Strack, 2009) by which the prime words are further processed and consolidated. However, our AB task had the advantage over the RAT of allowing novel comparisons between emotional vs. non-emotional stimuli. A wealth of prior research has demonstrated relationships between REM sleep and improvements on emotional memory tasks, including improvements in discrimination accuracy for facial emotions (Gujar, McDonald, Nishida, & Walker, 2011a), recall of emotional texts (Wagner, Gais, & Born, 2001), recognition of emotional pictures (Groch, Wilhelm, Diekelmann, & Born, 2013) and consolidation of complex negative scenes (Payne, Chambers, & Kensinger, 2012a). In our case, the emotional cue-words were preferentially consolidated over the non-emotional cue-words during REM sleep, since only AB scores for emotional cue-words were increased following REM sleep (Walker & van Der Helm, 2009). The results thus provide novel evidence that REM sleep functions in facilitating broad associative integration of recent emotional memory traces as described in the Introduction.

The use of positive and negative emotion cue-words allowed us to examine the effects of word valence more closely. Post-hoc analyses assessing differences in associational breadth

to positive and negative stimuli revealed that positive cue-words led specifically to more atypical word associations after REM sleep whereas negative cue-words led to an opposite effect. Although much of existing research has focused on the role of REM sleep in tasks involving negative emotions, there is also some indication that positive emotional stimuli are REM-dependent (Chambers & Payne, 2014; Gujar et al., 2011a). Further, previous work on associative access in waking cognition suggests that positive affect, in particular, facilitates spreading activation (Topolinski & Deutsch, 2013). Since high scores on our task presumably relies on broad spreading activation throughout semantic networks, the presence of positively toned cue-words may have further enabled this associative spread. In the waking state, positive mood improves success with RAT solutions (Corson, 2002; Haänze & Hesse, 1993; Isen, Daubman, & Nowicki, 1987) and increases the unusualness and diversity of word associations (Isen, Johnson, Mertz, & Robinson, 1985). Moreover, the emotional stimuli triggering such facilitation may be very brief in nature, such that phasic affective stimuli—including positively toned cue-words themselves—may temporarily facilitate spreading activation, what Topolinski and Deutsch (2013) refer to as the phasic affective modulation of semantic spread. To illustrate, brief activations of zygomaticus (smiling) muscles during the RAT facilitated finding successful solutions (Topolinski & Deutsch, 2013). Thus, in the present study, the emotionally positive words presented during the memorization task may have triggered a facilitation of semantic spreading that was subsequently consolidated during REM sleep.

Another possibility is that the positive emotion facilitation occurred during reactivation of the positively toned cue-words during the REM sleep naps. Several physiological systems necessary for emotional functioning fluctuate in a phasic fashion during REM sleep, e.g., facial muscle twitches, rapid fluctuations in heart rate, respiration and blood pressure, phasic sympathetic activation (Snyder & Scott, 1972). Some of these phasic events have been linked to emotional experience during dreaming, e.g., zygomaticus EMG and positive dream affect (Gerne & Strauch, 1985) or respiratory fluctuations and dream emotionality (Hobson, Goldfrank, & Snyder, 1965). While we did not assess these relationships, we might predict that increases in such phasic events would be correlated with higher post-sleep scores on the AB task—much as sleep spindles during NREM sleep predict post-sleep declarative or procedural memory performance increments (Clemens et al., 2005; Clemens, Fabó, & Halász, 2006;

Girardeau, Benchenane, Wiener, Buzsáki, & Zugaro, 2009; Huber et al., 2004). Nevertheless, the findings in this study provide initial support for a role of positive emotion in facilitating associative spread; findings from Study 2 further support a role of positive affect on associative access during REM sleep (see section 3.3.3).

In general, our findings support the validity of the emotional AB task as being sensitive to both the influence of REM sleep and the emotional valence of experimental stimuli. It has thus received initial construct validation as a task that is appropriate for assessing REM sleep-related emotional memory integration.

3.2.2 Support for a sequential model of memory consolidation

As predicted, we found that NREM and REM sleep awakenings led to different patterns of word association; specifically, only participants awakened from REM sleep responded with more uncommon word associations to emotional cue-words that had been primed prior to sleep. In contrast, participants awakened from NREM sleep responded with more common associations, similar to levels for the baseline condition, and did not differ for non-emotional and emotional cue-words. That the priming effect was selectively associated with REM, but not NREM sleep, seems initially consistent with a general dual-process model of sleep-dependent memory consolidation which claims that different sleep stages are selective in the elements of memory they process. At first glance, it even seems possible that the studied cue-words were not at all processed during NREM sleep, given the similarity in response patterns (common word associations) in both baseline and waking control conditions. However, our more complex sleep stage analyses gave evidence that the emotional cue-words were, in fact, sequentially modulated by both NREM and REM sleep states.

Specifically, we found that participants who had REM sleep early in their naps, but then proceeded into a second cycle of NREM sleep prior to awakening, still responded with common word associations on the AB task (see NREM2 in Figure 1). In other words, despite having had REM sleep, they responded with common word associations to cue-words as for the NREM only condition. This suggests that the cue-words were re-consolidated into the more structured and less hyper-associative networks of NREM sleep after the REM sleep episode occurred. If participants then went into a second cycle of REM sleep prior to awakening (see REM2 in Figure

1), they presumably returned to the hyper-associative conditions of REM sleep, and a REM priming effect was seen in the form of responding with broad and unusual associations to cue-words.

Figure 1. Sleep patterns of four groups for sequential task analyses

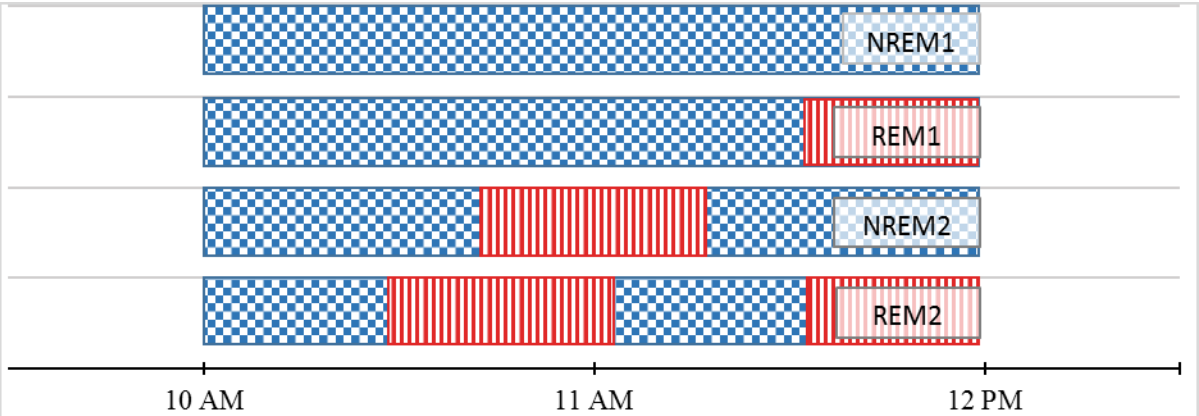

Figure 1. Participants were grouped according to stage at awakening. The topmost bar represents participants with only NREM sleep (NREM1). The second bar represents participants who had a period of NREM sleep followed by 10 minutes of REM sleep prior to awakening (REM1). The third bar represents participants who had NREM sleep followed by early REM sleep, then a second NREM sleep episode prior to awakening (NREM2). The bottom bar represents participants who had NREM sleep followed by early REM sleep, then entered a second NREM sleep episode and finally a second REM sleep episode prior to awakening (REM2).

These findings at once replicate prior research showing NREM and REM specific effects on semantic associativity and other, similar cognitive tasks (Bertini, Violani, Zoccolotti, Antonelli, & Di Stefano, 1984; Stickgold et al., 1999), but also provide new evidence for a sequential model which stipulates that a singular memory trace may be activated and re-activated and consolidated in each sleep stage. For example, REM sleep may have consolidated cue-words in broad associative networks, leading to more uncommon responses after awakening; however, entering into a subsequent period of NREM sleep may have undone this work, re-consolidating these cue-words in the relatively close semantic networks of NREM sleep and leading to more common semantic associations after awakening. Prior evidence showing that NREM and REM sleep differentially influence semantic associativity includes a study showing that quicker priming of weakly related semantic associates (e.g., thief-wrong) occurred after REM sleep awakenings, whereas quicker priming of strongly related associates

(e.g., 'hot-cold') occurred after NREM sleep awakenings (Stickgold et al., 1999). The weakly-related word pairs in that study are similar to the uncommon responses seen after REM awakenings for our AB task, whereas the strongly related pairs are similar to the common responses seen after NREM awakenings. Thus, in our study, while REM sleep clearly led to broader word associations, for those participants who went back into NREM sleep after REM sleep, the REM sleep effect did not appear. This may mean that the emotional cue-words were sequentially re-consolidated in the NREM state, characterized by limited spreading activation and consolidation of close semantic associations.

3.2.3 Evidence of Sleep to Forget/Sleep to Remember function of REM sleep

While our results strongly support a role for REM sleep in selectively increasing the strength of associations between emotional memory traces, our correlational analyses revealed a negative correlation between time in REM sleep and AB score. While unexpected, this negative correlation is actually similar to the finding (Stickgold et al., 1999) that only early night REM-awakenings led to increased priming for weakly-related word pairs, whereas later night REM-awakenings led to decreased priming for weakly-related word pairs. In other words, the longer and more physiologically intense REM periods of late night sleep led to less priming. One possible explanation for this is that the relative decrease in emotional priming over the night could be related to a general affect regulation function of sleep in general, or of REM sleep in particular (Cartwright, Agargun, Kirkby, & Friedman, 2006; Greenberg, Pillard, & Pearlman, 1972; Lara-Carrasco et al., 2009; Walker & van Der Helm, 2009). From this perspective, initial re-activation of the emotional cue-words in REM sleep may have triggered the formation and strengthening of broad associational connections; however, longer REM periods may have successfully downregulated the arousal associated with these emotional cue-words, weakening or at least no longer strengthening associations. Such an "affective-stripping" function of REM sleep has recently been proposed in the SFSR (Sleep to Forget/Sleep to Remember) model of emotional memory processing (Walker & van Der Helm, 2009). The SFSR model stipulates that connectivity of emotional memory traces develops in concert with the progressive diminution—within and across REM periods—of the emotional charge associated with those memory traces. In line with this model, the emotional cue-words that were studied prior to sleep by our participants may have been tagged for both consolidation and down-regulation in REM sleep.

Thus, initially the REM period resulted in strong AB priming effects, as our group analyses showed. However, as the REM period progressed, the emotional cue-words may have been progressively denuded of their emotional charge, resulting in the negative correlation between time in REM sleep and AB score.

Further, our finding that NREM and REM awakenings led to opposite patterns of associational response over multiple cycles, i.e. NREM primed typical associates, whereas REM primed atypical associates, suggests that the same emotional memory trace may be sequentially modified over multiple REM cycles, and potentially multiple nights. This is also in line with Walker's (2009) SFSR model, whereby repeated activation of emotional memory traces across multiple REM sleep periods over time leads to increasing consolidation of the memory trace and down-regulation of the "affective blanket" associated with the memory trace. In sum, findings from Study 1 provide evidence consistent with the SFSR model; these findings will be expanded in the discussion of Study 2, where results of our 1-week retest provide further evidence of integration and down-regulation of emotional memory traces over multiple cycles and nights (see section 3.3.5).

3.2.4 Qualities of morning nap dreams

A major innovation in Study 1 was to develop and assess the appropriateness of using daytime naps for dream research. Our finding that dream recall for NREM and REM naps was higher than usual, 89% for NREM naps, and 96% for REM naps, suggests that daytime naps may in fact be preferential to nighttime sleep for sampling dreams. Nighttime sleep produces recall of dreams at about 43% and 80% for NREM and REM awakenings (Nielsen, 2011). In our protocol, participants were given an opportunity to sleep starting at 10 am, and awakenings typically occurred between 11:30 am and 12 pm. This is during a circadian peak for REM sleep propensity, which has been found to correlate with dream recall (Dijk, Shanahan, Duffy, Ronda, & Czeisler, 1997; Nielsen, 2011). Further, dream characteristics such as character interaction, emotional content, and dream vividness have been found to increase for REM dreams across the night (Cohen, 1977; Domhoff & Kamiya, 1964; Kramer, McQuarrie, & Bonnet, 1980). Such findings support the notion that peak times for REM sleep propensity occur during morning naps (Mednick, 2006).

Our results extend to brief daytime naps findings that nighttime NREM and REM dreams differ in some qualitative respects. In particular, our finding of elevated scores for bizarreness in REM relative to NREM nap dreams directly replicates similar findings for REM and NREM night dreams (Casagrande, Violani, Lucidi, Buttinelli, & Bertini, 1996). Similarly, our finding of greater intensities of positive and negative emotion in REM than in NREM nap dreams replicates previous findings for nocturnal REM and NREM dreams (Foulkes, 1962). The elevated intensity of sensory experience of REM naps is also similar to that found in reports of nighttime REM dreams, which are more elaborate and vivid when compared to NREM dreams. Finally, we found that the PSG recording of morning naps is advantageous for a number of reasons: they require less personnel time (by about 50%) and are thus more cost effective; they take place during the daytime and thus are less harmful for technicians and experimenters otherwise required to work the night shift; and they are more accommodating for participants, who sacrifice less of their time and are not inconvenienced by a sleep-over at the laboratory.

In sum, our development of a new, morning nap protocol, demonstrated that such naps are an adequate and even advantageous method of collecting dream reports, given the higher levels of dream recall obtained and the replication of common REM/NREM report differences. On the practical side, naps proved to be cost-effective and less disturbing for volunteers and technical staff alike.

3.2.5 Comparisons between nap dreams and daydreams

Comparisons between naps and waking daydreams further demonstrate the utility of morning nap studies for contrasting imagery conditions while controlling for reporting procedures, time of day, and other factors. Our results suggest that emotion and sensory experience are selectively inhibited by NREM mechanisms, whereas bizarreness and sensory experience are selectively enhanced by REM mechanisms, both in comparison to wake. To clarify, emotional intensity (both positive and negative) in REM nap dreams is similar to that of waking daydreams (not higher than waking daydreams, as predicted), though emotion is specifically lower in NREM sleep. In contrast, bizarreness does not differ between daydreams and NREM dreams, though it is particularly high in REM dreams. Sensory experience in

daydreams was intermediate between that of NREM dreams, which had lower self-rated sensory experience, and REM dreams, which had higher ratings of sensory experience.

Given that REM sleep is particularly important for the consolidation and regulation of emotional memory (Groch et al., 2013; Nishida et al., 2009), it is possible that preserved emotion experience in REM sleep is essential for the proper consolidation of emotional memory at this time. Our finding that REM dream emotion intensity is as high as that of waking daydreams is consistent with previous findings that at least 2/3 of REM dreams contain emotion (Bechara & Naqvi, 2004; Cameron, 2001; Nielsen et al., 1991a; Pally, 1998). Contrary to REM based emotional memory consolidation, the NREM state is involved in direct episodic memory consolidation, and perhaps benefits from the absence of influence from emotional activity at this time (Smith, 2001). Thus, whereas REM sleep facilitates emotion and emotion memory processing, NREM state mechanisms may actively inhibit emotional experience, resulting in lower emotional intensity than that of waking daydreams or REM dreams, and more efficient episodic memory processing.

In a similar fashion, state differences in the other mentation attributes may be linked to other features of state-dependent memory processing. Bizarreness and sensory experience, which are lower in waking daydreams than in REM dreams, could be indicative of the rather structured networks of waking thought and the fact that our waking thoughts tend to be directed through conscious control (Corno, 1986) and focused on current tasks (Smallwood et al., 2003). In the NREM state, there is also low dream bizarreness, and even lower intensity of sensory experience, suggesting a memory network that is structured in a fashion similar to that of wake: focused on direct and immediate connections and playing a role in direct episodic replay and memory consolidation (Smith, 2001). This contrasts with REM dream reports, which were characterized by particularly heightened bizarreness and sensory experience, suggesting a more extensive level of memory activation than is present in either waking or NREM experience. This finding may again reflect REM sleep function, in that REM sleep is presumably hyper-associative as a means of encouraging emotional memory integration, as well as cross-modal sensory integration (Cai et al., 2009; Carr & Nielsen, 2015). The increased spreading activation taking place during REM sleep may lead to novel and unusual connections in memory networks, resulting in heightened dream bizarreness and sensory vividness. Further, the elevated sensory

experience is consistent with the fact that REM sleep is associated with visuo-motor and procedural learning (Aubrey et al., 1999; Plihal & Born, 1999), which may rely on activation of sensorimotor networks. Such broad activation of semantic and sensorimotor networks may enable fully immersive REM dream experiences (Christoff et al., 2011; Fox et al., 2013). Thus, in general, the imagery attributes of both NREM and REM dreams seem to parallel proposed memory consolidation functions of the two states.

3.2.6 A functional role for dreaming?

While we consider our finding of elevated REM dream bizarreness to reflect the hyper-associativity of semantic networks during REM sleep, we did not test whether dreaming actively participates in processes of memory integration. Nonetheless, several authors have previously considered dreaming to be implicated in memory consolidation, most notably the work of Wamsley, Tucker, Payne, Benavides, and Stickgold (2010) suggests that extent of incorporation of task stimuli into dream content is directly related to extent of memory consolidation. In their case, a fully immersive and engaging downhill skiing game was used, which reliably influenced dream content, probably due to the vivid and immersive nature of the task. In our case, there was very little evidence of task incorporation (cue-words) into dreaming, and thus this association would be a poor measure. Still, there is at least some evidence that semantic tasks can influence dreaming and further be correlated with learning. De Koninck et al. (1990) showed that progress in learning a foreign language was significantly related to the extent of foreign language incorporation into dreaming. It is possible that with repeated administration and assessment of our AB task, we might see some changes in dream content related to the task, and thereafter be able to assess relationships between dream content and learning.

Nonetheless, although the present findings do not demonstrate a role for dreaming in memory consolidation, they do indicate that morning nap dreams may be advantageous for further studies of dream content and memory consolidation for several reasons, besides the simple practicality of such a design. First, dream recall was relatively high for both NREM and REM naps, and attributes were qualitatively similar to reports from nighttime sleep. Moreover, whereas experiments employing a full night's sleep often use 8 hrs of daytime wakefulness for comparison, here we are able to simply use 2 hrs of morning wakefulness as a control. This

enables two things: first, control for any effect of circadian rhythm on task performance or imagery, and second, a laboratory controlled waking condition, e.g. the CTL participant follows the same protocol as other groups, including EEG hookup, quiet rest in the laboratory bedroom, and even recorded assurance that the subject was, in fact, awake the entire period.

3.2.7 Summary

In general, our findings replicate and unify prior research showing that REM sleep selectively consolidates emotional stimuli, and that REM sleep is uniquely hyper-associative compared to other states. These dual capacities of REM sleep may result in the adaptive integration of emotional memory traces over time. Our findings of elevated ratings of bizarreness, emotion and sensory experience in REM compared with NREM nap dreams parallels reports from dreams of nocturnal sleep. We speculate that REM and NREM mechanisms exert selective control over imagery attributes, and this selective control parallels functions of NREM and REM sleep for memory consolidation, specifically, that NREM sleep functions to facilitate consolidation of typical memory schema, whereas REM sleep enables broad spreading activation through memory networks and the integration and down-regulation of emotional memory traces.

3.3 Study 2

3.3.1 Nightmare sufferers have increased associativity in wake

Although the provisional hypotheses that NM sufferers would demonstrate restricted access to emotional semantic networks both in the form of lower AB task scores and longer RTs were not supported, findings nonetheless reveal telling differences between NM and CTL groups that allow us to propose novel conceptualizations of nightmare pathology. Our analyses of baseline associational breadth revealed that frequent nightmare sufferers have more unusual emotional semantic associations than do CTL participants, for both negative and positive cue-words. This effect was consistent one week later.

The unexpected finding that the NM group had higher baseline values for both negative and positive AB tasks lends considerable support to an alternative hypothesis that NM sufferers

have unusually broad associational capacities, at least for emotional stimuli. The lack of a difference in reaction times between the two groups in the presence of such consistent differences in AB suggests that performance on the task was rather automatic and not due to a purposeful strategy of searching for more 'creative' responses. That this difference was so robust suggests that broad associational ability may constitute a consistent trait associated with frequent nightmares, and in general agrees with anecdotal reports and prior findings that NM sufferers are endowed with artistic talent and creative thinking abilities.

While waking cognition research has shown that negative emotion leads to decreased performance on associative tasks, in our study we found higher AB scores in response to negative than to positive cue-words. One possible explanation for this discrepancy is that our task relies on relatively automatic processing whereas other associative tasks rely on active and controlled search through semantic networks. Research on waking cognition supports this notion in showing that automatic processing modes are mediated directly by emotional arousal, whereas controlled processing modes are mediated by emotional valence (Straube, Sauer, & Miltner, 2011). In other words, tasks that are completed rather automatically are not influenced by emotional positivity or negativity, whereas in tasks requiring controlled processing, negative emotion tends to restrict associative access while positive emotion broadens it. Our task may have been relatively more automatic because we asked participants for the first three words that came to mind; this is in contrast to associative tasks that require an active search through semantic networks to discover a solution, as is the case with the Remote Associates Task. By this explanation, only emotional arousal, not valence, would be expected to influence performance on our task. Our findings agree with this interpretation, since level of arousal is presumably higher in NM participants, and also higher for negative cue-words, both of which were associated with an increase in associational breadth.

In sum, NM sufferers showed increased associational breadth on a baseline task. Both NM and CTL groups may have performed the task relatively automatically, a presumption supported by the finding that groups did not differ in reaction times. It is possible that levels of arousal mediated performance on the task, with increased arousal in NM sufferers engendering faster or broader spreading of activation in semantic networks.

3.3.2 Nightmare sufferers have bizarre, affective daydreams

Consistent with our hypothesis, the NM group reported intensified daydreams, particularly for attributes of positivity, body sensation, and bizarreness, though they reported no differences in negativity. The lack of difference in negativity is striking given the presence of affective symptomology in our group; the analysis of questionnaire responses revealed that the NM group had higher nightmare-distress and alexithymia (DIF subscale) as well as a tendency to manifest depressive symptoms. Our findings again support an alternative view that NM sufferers have generally intensified dreaming, including more vivid and immersive daydream experiences, i.e., that are not defined only by negative affect (Levin & Nielsen, 2007; Spadafora & Hunt, 1990).

That NM sufferers had higher bizarreness ratings in their daydreams than did CTL participants is at once consistent with previous findings that NM sufferers are higher in fantasy proneness and creative aptitude (Hartmann, Russ, Van der Kolk, Falke, & Oldfield, 1981; Levin & Fireman, 2001) and that on our baseline task NM sufferers had broad associational capacities, particularly for emotional cue-words. Given that bizarreness in imagery may reflect hyper-associativity during REM dreaming, the same may be occurring during waking state daydreams for NM sufferers (Carr & Nielsen, 2015; Stickgold et al., 1999). Further, the elevated positivity NM sufferers' daydreams may have facilitated broad spreading activation, similar to effects seen in waking state tasks, and thus even further increasing imagery bizarreness (Garland et al., 2010; Isen et al., 1987; Isen et al., 1985).

The bizarre and positive daydreams of NM sufferers again support an alternative view of NM sufferers, i.e., that their waking imagery is as creative and enjoyable as their nightmares are repetitive and distressful.

3.3.3 Groups did not differ on REM priming effect: novel effects of valence

Unexpectedly, NM and CTL groups did not differ in task performance following REM sleep; both groups showed similar REM-dependent changes in associational breadth, with their associations becoming more unusual in response to positive cue-words yet more common in response to negative cue-words. These findings expand on the findings of Study 1, which showed that it was specifically positive, not negative cue-words that led to increased AB

following REM sleep (see section 3.2.1). As predicted, when participants were awakened from REM sleep and asked to provide word associations to positive cue-words that had been primed prior to sleep, the semantic atypicality of responses increased relative to cue-words that had not been primed. We assume that the positive cue-words were activated during REM sleep, leading to strengthening of broad associations in their semantic networks.

Our results extend these findings to show a comparatively negative priming effect for negative cue-words. While this is a new finding, it is in accordance with research on waking cognition. Specifically, a differential influence of positive and negative emotions on associational access during waking state tasks is well-established. For example, induction of positive affect leads to the production of more broad semantic associations in the laboratory (Isen et al., 1985); on the other hand, sadness leads to more constrained and specific item processing (Storbeck & Clore, 2005). In the present study, the emotionally positive cue-words may have facilitated semantic spreading during REM sleep, perhaps even through dreaming (see section 3.2.1). Further, primed reaction times differed by valence, with faster responses occurring for positive than for negative cue-words; this suggests that positive valence correlated with both increased breadth *and* speed of associative access. These consistent findings not only further validate the notion of affect-mediated semantic network access, they also extend these effects for processes linked to sleep and support our AB priming task as a valid measure of this differential effect.

The unexpected lack of a difference between NM sufferers and CTL participants in this study suggests that REM sleep maintains its properties of heightened associativity despite the presence of frequent nightmares. Nonetheless, it is possible that emotional memory integration occurs gradually over multiple sleep cycles or nights, and thus a group difference may not be evident over the course of a single nap (discussed in section 3.3.5).

3.3.4 Bizarreness and affect in dreams did not differ between groups

Contrary to predictions, the nightmare group did not show higher overall negativity, positivity or bizarreness in their nap dreams. These results nonetheless corroborate our additional finding that NM participants did not differ from CTL participants on task performance following a REM sleep nap. Assuming that dream bizarreness reflects the associative nature of

REM sleep, that our two groups did not differ in either dream bizarreness or patterns of REM sleep-dependent AB suggests that, to some extent, REM mechanisms of associative spreading activation may remain intact in NM sufferers. Another possibility, given that both groups had a significant elevation in bizarreness levels in their dreams compared to daydreams, is that there may be a ceiling effect, with both groups experiencing maximally bizarre and associative REM sleep memory processing.

The lack of a difference in negative affect ratings between groups is difficult to explain, given the clear role of negative affect in the habitual nightmares of the NM group. It is possible that some aspect of our nap methodology was responsible for this lack of an effect (along with the fact that none of our participants reported full-blown nightmares during their naps). One possibility is that participants' emotions had already been down-regulated from the prior night's sleep, or that the lab environment itself served as a form of 'safe' environment that softened the affective content of dreams (LaBerge & Rheingold, 1990). However, the nap dreams of the NM group did contain elevated levels of body sensations, thus there does seem to be evidence of heightened levels of emotional arousal occurring within the dream imagery of nightmare sufferers (see section 3.3.6).

In any case, at least within the morning nap recorded in the laboratory, the nap dreams of NM participants did not differ from those of CTLs in either bizarreness or affect, and this parallels our task findings that NM participants did not differ from CTLs in emotional semantic associations following REM sleep.

3.3.5 Nightmare group shows disrupted Sleep to Forget/Sleep to Remember process

Despite the lack of a group difference in immediate REM sleep-dependent priming effects, differences did emerge at the 1-week re-test; the NM group continued to respond with more unusual positive yet more common negative semantic associations, whereas the CTL group returned to baseline patterns of association for both. Further, the CTL group displayed a quickening of reaction time at re-test, whereas the NM group did not. It is possible that, for the CTL group, initial REM sleep-dependent changes in associative access dissipated as the emotional cue-words became either fully integrated into memory or fully stripped of their

affective charge over time, and one week later the cue-words benefited from strengthened consolidation and faster speed of access (Walker & van Der Helm, 2009). For the NM group, however, the initial REM sleep-dependent changes in associative access may not have dissipated, possibly because the cue-words were not fully integrated into memory or because their affective charge was not down-scaled over the 1-week delay. In either case, speed of accessing the words did not improve.

Such a temporal pattern of memory integration and re-consolidation has been theorized and supported to some extent (Walker, 2009). For example, in Study 1 we found that REM sleep awakenings led to increases in AB, although time in REM sleep was negatively correlated with AB. We interpreted this finding as supporting the SFSR model; in other words, while REM sleep does broadly associate memory traces, it also decreases the affective charge of emotional memory traces. Perhaps as the REM period continued, the relative decrease in affect likewise dampened the spread of activation, or even weakened the strength of associations within memory networks. Over many sleep periods, this pattern may lead to a progressive integration of memory traces and a down-regulation of their associated affect. It is possible that the NM group is less efficient at this process, resulting in sustained priming effects one week later. There are several potential explanations for this: heightened arousal at encoding or sustained arousal over time may have led to a more resistant priming effect; lower REM efficiency could have delayed full integration or regulation; the experience of nightmares during the 1 week delay could have interfered with integration or regulation. Although further study is needed to examine these specific possibilities, our results in general imply that NM sufferers are less efficient at integrating emotional experiences into memory over the long term.

3.3.6 Elevated body sensations in imagery of nightmare group

Our finding that body sensations were significantly more frequent in both the daydreams and nap dreams of NM sufferers suggests a physiological peculiarity in NM sufferers that may be related to hyperarousal, or hypervigilance, and in dysregulated bodily arousal. That we found heightened body sensations, yet no difference in either positive or negative attribute categories in the dreams of NM sufferers suggests that there is something particular to body sensations that was not captured by other emotional rating items. Given the ubiquity of emotion in dreaming

and particularly in nightmares, body sensations such as pleasure and pain may be particularly relevant attributes to assess in the imagery of nightmare sufferers. Of note, intensified dreaming, including nightmares, is often distinguished by more complex and immersive kinesthetic imagery (e.g. vibrations, floating, disintegration) than what is found in mundane dreams (e.g. weight, paralysis; Hunt, Gervais, Shearing-Johns, & Travis, 1992; Kuiken, Carey, & Nielsen, 1986). Further, while NM participants are characterized by heightened arousal to emotional experience, they also have been found to experience difficulty in articulating and identifying their emotions; this was confirmed in our finding that our NM group had higher Alexithymia (difficulty identifying feelings subscale) scores. In fact, one theory of alexithymia suggests that hyperarousal itself interferes with identifying feelings. Therefore, investigations of body sensation may be particularly valuable in this population in providing more sensitive measures of emotional arousal than cognitively oriented emotional ratings (e.g., emotional frequency, intensity, fear).

While the finding of elevated body sensation in NM sufferers is relatively novel, it may well be consistent with previous findings that NM sufferers rate their home dreams as containing more inhibition/ineffectuality, which could be considered a highly negative body sensation (Nielsen et al., 2010b). Furthermore, the current findings suggest that not only negative, but also positive body sensations are elevated in the dreams and daydreams of NM sufferers. Together, the findings suggest that the imagery of NM sufferers is consistently characterized by more salient or more vivid body sensations, of both a negative and positive valence (e.g., pain or pleasure). In the case of nightmares, negative body sensations such as inhibition/ineffectuality may result in increasing anxiety, fear, and nightmare awakenings. In the case of positive imagery, pleasurable sensations could result in more intense erotic dreams or flying dreams.

In sum, our finding that both negative and positive body sensations were heightened in the waking and dreaming imagery of NM sufferers further supports an alternative, more inclusive, approach to explaining nightmares. Contrary to traditional perspectives which focus exclusively only on negative nightmare imagery, NM sufferers in fact may be more accurately characterized as experiencing intensified imagery of both negative and positive valences.

3.3.7 Support for an alternative approach to nightmares

Our findings support a broader portrait of the nightmare sufferer than is typical in the literature. In waking, NM sufferers display broad and unusual emotional associations, corresponding with anecdotal reports of heightened creativity and artistic expression. They also experience vivid, positive, and bizarre daydreams. However, NM participants show a prolonged priming effect and do not improve in reaction times on the AB task over a 1-week interval like control subjects do; their emotional experiences may take longer to fully integrate. Further, our NM group possesses certain negative affective symptoms, including higher scores on NM-distress, alexithymia, and depression. Thus, our findings suggest that individuals experiencing frequent nightmares at once benefit from associational and imaginative capacities advantageous in creative pursuits, while also suffering from inadequate emotional memory integration and a propensity to affective disorders and distress.

These complementary sets of findings have led us to develop a novel explanatory framework which proposes that frequent nightmare sufferers are sensitive and responsive to a wider than normal range of environmental influences, including not only stressors but also positive and perceptually rich experiences. This sensitivity may be reflected in a range of different types of intensified imagery experiences, not only in nightmares. The following section builds on an existing model, the Affect Network Dysfunction model of nightmares, in order to develop a novel Environmental Sensitivity model of nightmares. The implications of Environmental Sensitivity for psychopathology, risk for PTSD, and treatment will be discussed thereafter (sections 3.5, 3.6).

3.4 Expanding the Affect Network Dysfunction model of nightmares: Individual differences in Environmental Sensitivity

Traditionally, theories and research surrounding nightmares have focused on the nightmare as a symptom and its associated negative outcomes, such as nightmare distress, which together situate nightmares squarely within a diathesis-stress framework. Diathesis-stress frameworks propose that individuals vary in the degree to which they are affected, short and long term, by life stressors such as abuse, childhood maltreatment, and trauma (Monroe &

Simons, 1991; Zuckerman, 1999). In particular, such frameworks assume that certain individuals are inherently vulnerable to such stressors, perhaps due to genetic factors, personality traits (e.g., difficult temperament) or physiological reactivity (e.g., high stress reactivity). For example, children who score high on negative emotionality have been shown to experience more adverse effects when exposed to harsh parenting, compared to children scoring low on the same trait (Belsky, Hsieh, & Crnic, 1998). In other words, negative emotionality renders children more vulnerable to the environmental stressor of harsh parenting.

A major diathesis-stress model of nightmares is the Affect Network Dysfunction (AND) model, which posits two main factors as responsible for the development and expression of nightmares: *affect distress*, a personality trait similar to negative emotionality that develops in response to adversity, and *affect load*, the current emotional demands on the organism (Nielsen & Levin, 2007). Corroborative evidence for this model includes empirical findings that negative personality traits, such as neuroticism or hyperarousal, along with a history of adverse experiences, are correlated with nightmare frequency and a host of concurrent negative symptoms including nightmare distress, alexithymia, anxiety, and depression. However, diathesis-stress frameworks are inherently biased toward psychopathology, and we argue that by limiting focus to negative symptoms, stressors, and the nightmare experience itself, researchers are neglecting potentially complementary evidence that nightmare sufferers show adaptive response to positive environmental contexts.

Recently, several frameworks have emerged from evolutionary psychology that challenge the current bias towards diathesis-stress thinking and instead describe individuals as varying in their response to a wide spectrum of contexts, not just in response to stressors. The theory of differential susceptibility proposes that individual diatheses emerge not only in response to adverse or traumatic contexts, but also in response to positive or supportive contexts (Belsky, Bakermans-Kranenburg, & Van IJzendoorn, 2007; Belsky & Pluess, 2009). The authors stress the fact that diathesis-stress frameworks, and the empirical research supporting such frameworks, have often failed to consider the possibility that sensitivity may extend to positive environments and adaptive outcomes. Boyce and Ellis (2005) proposed a similarly bi-valent theory regarding the trait of physiological reactivity (Boyce & Ellis, 2005). Again, although reactivity has traditionally been viewed pathogenically, Boyce and Ellis propose that

heightened stress reactivity may reflect, not simply exaggerated arousal under challenge, but also an increased Biological Sensitivity to Context (BSC), with potential for negative effects under conditions of adversity and positive effects under benign or supportive conditions. Empirical support was shown in one study in which young adults rated perceived stress on exam and nonexam days; those with the short version of the serotonin transporter gene (5-HTTLPR), a genetic indicator of stress reactivity, reported both higher stress on exam days and lower stress on nonexam days than controls. In other words, stress reactivity was heightened in response to adversity, but lower in benign contexts (Van Ijzendoorn, Belsky, & Bakermans-Kranenburg, 2012). Finally, sensory processing sensitivity is a personality trait that has been associated with higher emotional and physiological reactivity in response to both negative and positive contexts. Besides emotional contexts, sensory-processing sensitivity is associated with greater awareness of sensory stimulation and deeper cognitive processing of environmental stimuli (Aaron, 1996; Aron & Aron, 1997).

In sum, while diathesis-stress focuses on vulnerability to adversity, the latter theories extend the concept of sensitivity, whether psychological or physiological, to positive and supportive contexts, and suggest sensitivity may even entail heightened sensory and cognitive processing of the environment. Increasing support for these novel frameworks has led to the recent call for an umbrella term to encompass this bi-valent and multi-modal *Environmental Sensitivity* factor (Pluess, 2015). We argue that our recent findings diverge from traditional diathesis-stress thinking and would be better explained by an Environmental Sensitivity framework. For example, that our NM sufferers showed heightened semantic associativity can be seen as experimental evidence of heightened creativity, an adaptive trait, corroborating observational and occupational reports. Further, that our NM sufferers exhibited positive and bizarre waking imagery suggests they experience enriched and positive imagery along with their nightmares.

Therefore, we here expand on an existing diathesis-stress model of nightmares, the AND model, in order to develop a broader Environmental Sensitivity framework for nightmares. In the first place, the developmental evidence for the AND model of nightmare sufferers, including the established relationship between childhood adversity and nightmares, would likewise support an Environmental Sensitivity framework, since these frameworks similarly emphasizes

the role of developmental contexts in increasing sensitivity over time. However, our Environmental Sensitivity framework expands on the concept of affect distress to instead implicate a sensitivity to a range of affective, cognitive, and perceptual stimuli as opposed to only stressful or negative emotional events. In particular, findings of increased boundary thinness and increased motor-affective resonance in nightmare sufferers, along with our recent findings of heightened semantic associativity will be presented as preferential evidence for heightened trait-like Environmental Sensitivity. We then expand on the concept of affect load; we argue that Environmental Sensitivity to a range of stimuli, not only stressors, is reflected in a range of intensified imagery experiences of both negative and positive valences. Finally, the implications of Environmental Sensitivity for REM sleep-dependent emotional memory processing, psychopathology, PTSD risk, and nightmare treatment will be discussed.

3.4.1 The developmental perspective of Environmental Sensitivity

The Environmental Sensitivity approach is consistent with the developmental tenets of a diathesis-stress model in supposing that exposure to stressors during development may be associated with increasing Environmental Sensitivity in predisposed individuals. Thus, findings that childhood adversity or abuse, as well as accumulated emotional trauma are associated with increased nightmare frequency, nightmare distress, and psychopathological symptoms are all consistent with the Environmental Sensitivity model. Several recent studies have demonstrated a role for early adversity in the development of frequent nightmares. For example, one study found that women with a history of severe childhood maltreatment reported more frequent disturbed dreams, higher nightmare distress and heightened psychopathology (Duval, McDuff, & Zadra, 2013). Another found that accumulated traumatic experiences, specifically emotional trauma, combined with the presence of thematic dream content such as being pursued or experiencing frequent nightmares, were predictive of psychopathological symptoms (Yu, 2014). The severity and amount of trauma were both correlated with several dream and pathological measures, suggesting that the accumulation of traumatic experiences may have a graded effect on dream dysphoria. These results are consistent with the assumption that a history of adverse experiences can developmentally amplify inherent trait factors, such as affect distress or Environmental Sensitivity, which are potentially implicated in the psychopathology of nightmares.

However, the diathesis-stress model emphasizes the developing trait factor, affect distress, as a progressively growing disposition to experience heightened distress and negative affect in response to negative emotional events. Neurological research on the effects of childhood adversity have similarly focused on the relationship between childhood adversity and negative emotional reactivity; for instance, repeated stress inducing changes in the PFC–amygdala circuit that are associated with heightened threat perception (Ochsner & Gross, 2005). In other words, repetitive exposure to aversive stimuli may lead to progressively more intense affective and behavioral responses due to inadequate top-down control of the prefrontal cortex on the amygdala, particularly during stress appraisal (Loman & Gunnar, 2010). The AND model implicates this increased threat perception in dysphoric dreaming and nightmare production, particularly claiming that increased fear expression in the amygdala is responsible for dysphoric dreaming (Nielsen & Levin, 2007). However, contrary to the outdated view that the amygdala functions to detect and process only fearful stimuli (Adolphs et al., 1999; Davis & Whalen, 2001), recent research shows that it responds even more strongly to positive stimuli (Sergerie, Chochol, & Armony, 2008). Environmental Sensitivity frameworks take this into account. For example, one study of sensory-processing sensitivity found that highly sensitive individuals rated both negative and positive images (especially positive ones) as significantly more emotional than low sensitive individuals; further, they tended to respond faster to positive images (Aron, Aron, & Jagiellowicz, 2012). Thus, developmental changes in trait sensitivity likely entail increased reactivity in response to both negative (e.g. fearful) and positive environmental contexts.

Further, this developmental sensitivity may extend into other facets of perception and cognition; for instance, one study found that healthy adults carrying 5-HTTLPR short-alleles (a marker of stress reactivity) showed attentional bias to both negative and positive emotional stimuli, compared to neutral stimuli, suggesting increased visual attention may be a mechanism implicated in emotional sensitivity (Beevers, Wells, Ellis, & McGeary, 2009). Other studies found evidence of increased sensitivity even in the absence of emotionally toned stimuli. For example, highly sensitive individuals, compared to low sensitive individuals, showed stronger activation in brain regions for visual perception and attention processing when asked to notice subtle differences in landscape photographs, suggesting that they have heightened awareness of

and attention to subtle stimuli (Jagiellowicz et al., 2011). In another study, infants rated high on negative emotionality were found to look longer at novel stimuli, suggesting increased visual attention and cognitive engagement for novel environments (Vonderlin, Pahnke, & Pauen, 2008).

To summarize, both diathesis-stress and Environmental Sensitivity frameworks suppose that childhood adversity may lead to developmental changes in the central nervous system (e.g. prefrontal cortex, amygdala, and hippocampus) that underlie increased perception and response to environmental influences. However, Environmental Sensitivity proposes that heightened central nervous sensitivity, reflected in corresponding physiological (e.g., high stress reactivity) and psychological/behavioral traits (e.g., negative emotionality), is elicited in response to a range of environmental contexts, including both negative and positive emotion-eliciting events, and expanding to other elements of the environment, such as perceptual and cognitive processing of experience.

3.4.2 Beyond affect distress: Evidence for trait-like Environmental Sensitivity

In the AND model, *affect distress* is the overarching diathesis factor that renders nightmare sufferers particularly vulnerable to experiencing distress in response to nightmare expression, which can contribute to psychopathology (Nielsen & Levin, 2007). In regards to behavioral and psychological characteristics, affect distress is similar to both the negative affect and neuroticism personality dimensions, broadly involving heightened emotional reactivity (Chorpita & Barlow, 1998; Clark, Watson, & Mineka, 1994; Watson & Pennebaker, 1989). Several studies have reported correlations between nightmare frequency and such negative affect personality traits, including neuroticism (Schredl, 2003; Zadra & Donderi, 2000), psychoticism (Hartmann, Russ, Oldfield, Sivan, & Cooper, 1987), borderline personality and schizotypy (Hartmann et al., 1981), heightened concerns with death (Feldman & Hersen, 1967), and suicidal ideation (Cukrowicz et al., 2006), suicide attempts (Sjöström et al., 2009) and death by suicide (Tanskanen et al., 2001). In general, these maladaptive personality traits have been considered risk factors that are aggravated in the presence of stressors and relate to ineffectual or over-reactive emotional responses.

However, more recent studies with Environmental Sensitivity approaches have shown that emotional reactivity (even 'negative emotionality') is also sensitive to positive and supportive environmental contexts, as shown in the finding that individuals with higher stress reactivity experience both more stress during exam days, and less stress during non-exam days, than controls (Van Ijzendoorn et al., 2012). In other words, heightened stress reactivity was related to more adaptive functioning in a benign context. Likewise, in the case of nightmare sufferers, who may exhibit heightened affect distress and negative emotional reactivity, this reactivity may counter-intuitively extend to positive contexts. Further, Environmental Sensitivity may extend beyond affective experience, to perceptual and cognitive processing of the environment. While empirical research assessing sensitivity across a range of stimuli is lacking, there have been several trait-like factors characterizing nightmare sufferers that could fall under the bi-valent and multi-modal umbrella of Environmental Sensitivity. First and foremost, the trait of thin boundaries as defined by Hartmann is most similar to Environmental Sensitivity in describing an increased sensitivity and fluidity between emotional, perceptual, and cognitive domains (Hartmann, Elkin, & Garg, 1991; Levin, Galin, & Zywiak, 1991; Schredl, 2003). Second, an increased propensity for mirror behaviors, particularly motor and affective behaviors, may reflect increased perceptual and affective sensitivity in nightmare sufferers (Nielsen, Powell, & Kuiken, 2013). Third, our recent finding of heightened emotional semantic associativity, along with qualitative reports of creativity, suggest increased cognitive processing of emotional stimuli in nightmare sufferers (Carr, Blanchette-Carrière, Marquis, Ting, & Nielsen, 2016).

3.4.2.1 Boundary thinness

Hartmann, in his lifelong work as a psychiatrist, described nightmare sufferers as being generally more open, sensitive, and affected by their experiences (Hartmann, 1981, 1984). He developed the construct of boundary thinness to describe this sensitivity, and outlined several of the same principles as Environmental Sensitivity. *Thin-boundaried* individuals are considered to be highly susceptible to affective and perceptual experiences, and have increased fluidity across domains; for example, their feelings easily influence their thoughts and perceptions. Boundary thinness has been related to enhanced dream recall, increased dream bizarreness, greater cognitive fluidity, and elevated nightmare frequency (Hartmann et al., 1981;

Kunzendorf, Hartmann, Cohen, & Cutler, 1997; Levin et al., 1991; Pietrowsky & Köthe, 2003; Schredl, Schäfer, Hofmann, & Jacob, 1999). Further, individuals with thinner boundaries have been found to have increased visuospatial imagination abilities and better subliminal perception (Levin, Gilmartin, & Lamontanaro, 1998). Finally, boundary thinness is associated with having artistic occupations. For example, art students, compared to financial workers, have thinner boundaries, along with higher dream recall, greater dream vividness, heightened emotional imagery, increased lucid dream frequency, and higher scores of creativity (Levin et al., 1998).

Boundary thinness is thus similar to the Environmental Sensitivity trait of sensory-processing sensitivity. In their theoretical framework, Aron and Aron (2012) state that individuals who possess higher sensory-processing sensitivity have increased awareness and processing of subtleties in surroundings, but a tendency to be more easily overwhelmed and distressed when in a highly stimulating environment (Aron et al., 2012). The subscales of sensory-processing sensitivity – ease of excitation, low sensory threshold, and aesthetic sensitivity – very closely resemble several of the items in the boundary questionnaire, e.g., "I am very sensitive to other people's feelings", "I am unusually sensitive to loud noises and to bright lights," and "When I listen to music, I get so involved it is difficult to get back to reality". Although boundary thinness is distinct in its focus on inner imagination, fantasy proneness, and confusion between states of consciousness (e.g. "My dreams are so vivid that even later I can't tell them from waking reality"), its relationship to nightmare frequency and similarities with sensory-processing sensitivity support the concept of general Environmental Sensitivity as an encompassing trait-like disposition in frequent nightmare sufferers. Further, its similarities with sensory-processing sensitivity suggest that analogous processes may underlie both traits, and that sensory-processing sensitivity is a viable personality trait factor to study in nightmare sufferers.

3.4.2.2 Motor-affective resonance

A behavioral trait that has only recently been assessed in relation to nightmares is the individual propensity for mirror behaviors. Mirror behaviors in general refer to an individual's tendency to empathize with another's emotions or to imitate motor behaviors or speech; these behaviors are thought to reflect the activity of the mirror neuron system. Neuroimaging studies

of the mirror neuron system have shown that the same brain areas are active both while performing a specific action oneself (e.g., grasping something), and while observing that action in another (e.g., seeing a friend grasp something)(Decety et al., 1997). In fact, the same brain area is active when merely imagining performing an action, or imagining another person performing that same action (as in dreaming). This mirroring extends to emotional expression, as well (e.g., smiling, laughing). The mirror neuron system is thought by some to allow humans to understand and empathize with the actions and emotions of others, perhaps during dreaming as well as waking.

While mirror neurons have typically been assessed through neuroimaging, Nielsen and Kuiken (2013) developed the Mirror Behaviors Questionnaire to assess the most common behavioral manifestations of mirror neuron activity, such as contagious crying, laughing, and motor mimicry, among others. The authors found that nightmare frequency was associated with an increased tendency to express waking mirror behaviors (Nielsen et al., 2013), particularly on items of motor resonance for females, and one item of empathy, which together are interpreted to reflect elevated motor-affective resonance in female nightmare sufferers. This finding also provides preliminary evidence that nightmare sufferers may experience heightened empathy.

Studies of sensory-processing sensitivity have similarly found that highly sensitive individuals display heightened responsivity to emotional expressions in others. In a brain imaging study, researchers found that highly sensitive individuals had increased activation of the insula, inferior frontal gyrus (IFG), and cingulate when viewing images of their partner or a stranger making emotional expressions (Acevedo et al., 2014). Together these areas are implicated in heightened emotional processing, mirror neuron activity, and empathy. For instance, the insula is implicated in limbic functions, sensorimotor integration, and a wide range of functions including attention, emotion, and empathy (Cauda et al., 2011; Jabbi & Keysers, 2008; Phan, Wager, Taylor, & Liberzon, 2002). The insula further shows connectivity with the IFG, which showed increased activation for positive emotion conditions in this study, and is proposed to be part of the mirror neuron system (Jabbi & Keysers, 2008). Numerous studies have shown activation of the IFG for both the observation and execution of movements (Decety et al., 1997). Further, the heightened activation in the cingulate is thought to reflect empathy, as shown by a meta-analysis of 40 empathy studies (Fan, Duncan, de Greck, & Northoff, 2011),

which included the findings that the cingulate is involved in the recognition of other' actions, along with greater attention and alertness to socially relevant stimuli. The authors conclude that highly sensitive individuals are more responsive to others' affective states and actions, conclusions similar to those of Nielsen and Kuiken (2013) in their description of motor-affective resonance in nightmare sufferers.

In this manner, heightened Environmental Sensitivity may enable individuals to be more aware of social aspects of the environment; accordingly, Environmental Sensitivity has been described as adaptive for social functions and facilitating increased responsiveness to others' needs. Several studies of genetic and physiological factors related to Environmental Sensitivity have revealed socially relevant advantages to these traits. In one study, adults were asked to monitor and report each day for 9 weeks their positive emotions and the degree to which they felt socially connected; those adults with higher initial levels of vagal tone (a measure of physiological reactivity) increased in positive emotions and social connectedness more rapidly than others over the 9 weeks (Kok & Fredrickson, 2010). The authors conclude that individuals with heightened physiological reactivity, when placed in a positive context, experience more positive feelings, like curiosity and excitement. These positive feelings promote better responses, such as social connectedness, which in turn feed back to create more positive feelings, and so on, in what they call "upward spiral dynamics" (Kok & Fredrickson, 2010). Likewise, Environmental Sensitivity and motor-affective resonance in nightmare sufferers may afford certain social advantages, particularly within positive social contexts.

3.4.2.3 Semantic creativity

Our recent study of semantic associativity in frequent nightmares provides some of the first empirical evidence that nightmare sufferers may experience more widespread semantic activation in response to word stimuli (Carr et al. 2016). In the study, participants were presented an emotional word stimulus, and asked to respond with three meaningfully associated words within 30 seconds; their responses were compared to a normative list of the most common word associations given for each stimulus. Results showed that frequent nightmare sufferers, when compared to a control group without nightmares, had higher associational breadth, that is, more uncommon associations in response to both negative and positive cue-words. These effects were

replicated with a 1-week follow-up test. The findings suggest that nightmare sufferers have unusually broad associational capacities. Further, there were no differences in reaction times between the two groups, suggesting that performance on the task was rather automatic, and not due to active search for more 'creative' responses. These findings corroborate anecdotal reports that nightmare sufferers benefit from artistic talent and creative thinking abilities.

This propensity to widespread semantic activation in response to emotional semantic stimuli parallels claims that Environmental Sensitivity entails deeper cognitive processing, particularly of emotional stimuli (Aron et al., 2012). For instance, sensory-processing sensitivity is proposed to promote depth of cognitive processing via increased "semantic depth and differentiation" that is driven by emotional motivation (Patterson & Newman, 1993). In other words, it may be that among high environmentally sensitive subjects emotional arousal promotes deeper information processing due to the relevance and importance of emotional information (Baumeister, Vohs, DeWall, & Zhang, 2007). We similarly speculated that the heightened spread of activation in emotional semantic networks in nightmare sufferers may have been driven in part by their increased arousal.

In sum, our findings suggest that Environmental Sensitivity, in this case sensitivity to emotional semantic stimuli, may engender deeper cognitive processing and widespread activation in semantic networks in nightmare sufferers. Such a pattern may be advantageous in creative pursuits. However, it is possible that over-stimulating environments may result in disorganized or schizotypal thoughts, both of which have been found in nightmare sufferers (Claridge, Clark, & Davis, 1997). For instance, in one recent study, researchers found that nightmare sufferers showed more perseveration on a verbal fluency task, e.g., repeated or ineligible responses, while they did not differ from controls in total verbal fluency score (Simor et al., 2012b). The extent of perseveration was significantly related to state anxiety. It is possible that the anxiety of performing in front of an experimenter and trying to think of as many responses as possible within the timeframe could have caused nightmare sufferers to make more perseveration errors. This parallels claims of Environmental Sensitivity, that individuals have increased depth of processing, but also have a tendency to be more easily overwhelmed and distressed in a highly stimulating environment. In our case, the relative ease and automaticity of the Associational Breadth task led to broad semantic associations in nightmare sufferers;

however, in the verbal fluency task, heightened state anxiety may have interfered with cognitive and semantic processing.

3.4.2.4 Summary

The empirical findings of increased boundary thinness and a propensity to mirror behaviors, along with evidence of increased semantic associativity and creativity in nightmare sufferers, suggest that the individual trait characteristics of this population are not exclusively maladaptive. Instead, nightmare sufferers seem to be characterized by an overarching trait factor that encompasses a general increased sensitivity to affective, perceptual and cognitive stimuli. We propose Environmental Sensitivity to be a more appropriate trait factor to define nightmare sufferers, expanding the focus away from vulnerability as in the AND model, and towards more general sensitivity. The extent to which the environment is highly stimulating may then influence imagery processes, as reflected in the varied intensified imagery of nightmare sufferers, detailed in the following section.

3.4.3 Beyond affect load: Environmental load and intensified imagery

According to the AND model, increases in stress or emotionally negative events constitute an increase in affect load, which can influence an individual in both waking and sleeping states and result in bad dreams and nightmares. In susceptible individuals (those with high affect distress), these nightmares may cause significant distress and diminish quality of life. This is generally supported by findings that idiopathic nightmares increase during periods of stress (Barrett, 2001). However, the AND model refers only to the experience of dysphoric dreaming, despite the fact that nightmare sufferers may also experience positive and even intensified positive dreaming. We propose that intensified dreaming of either valence is determined by an accumulation of environmental load, which may consist of exposure either to stressors or to intense positive events, and may even include perceptually or cognitively loaded environments. In other words, an Environmental Sensitivity framework proposes that bi-valent and multi-modal environmental load may trigger an intensification of imagery processes. The multiplicity of intensified imagery experienced by nightmare sufferers across both waking and sleeping states and qualified by heightened emotion, kinesthetic and sensory richness, and bizarreness provides support for this notion of environmental load.

We also discuss the possibility that intensified imagery reflects REM sleep-dependent memory processing, particularly its broad and multi-modal integration of emotional experiences within memory networks. While the AND model focuses on a fear extinction function of dysphoric dreaming, the Environmental Sensitivity framework also looks to positive dream experiences for their potential function in memory integration. As mentioned, several attributes of dreaming are thought to reflect REM sleep-dependent emotional memory integration, particularly the emotional intensity, bizarreness, and sensorial vividness of dreams; intensified dreaming may likewise reflect an intensification of underlying REM sleep memory processing.

3.4.3.1 Nightmares

An Environmental Sensitivity framework differs least from the AND model in its description of nightmares; both assume that negative emotion-eliciting events and stressors accumulated during waking life trigger the expression of dysphoric imagery and nightmares. The AND model proposes that increases in affect load (e.g., divorce, job loss) lead to a prominent activation of relevant fear memories, which require integration and extinction during REM sleep. Presumably, fear memories that are too intense will result in nightmare awakenings and temporary failure in this fear extinction function. However, over time and many iterations of this process, dysphoric dreams may successfully recombine fear memories with non-aversive memory elements in novel contexts, functionally extinguishing fear memories and denuding them of their emotional charge. The model is generally supported by findings that subjects who report cessation of prior recurrent (presumably dysphoric) dreams score higher on well-being measures than do subjects who continue to experience recurrent dreams (Brown & Donderi, 1986). Further, increases or decreases in well-being over several years are accompanied by parallel changes in dream content, consistent with the suggestion that negative affect in dreams is determined by current affect load, and that extinguishing negative affect through dreams then generalizes to higher well-being during wake (Pesant & Zadra, 2006).

Environmental Sensitivity differs from the AND model by suggesting that nightmares may be qualified by any form of intense negative emotion, not only fear. Thus, while the AND model focuses on REM sleep-dependent fear extinction specifically, the Environmental Sensitivity framework is relevant for more general processes of REM sleep-dependent

emotional memory integration (not just fear memories). REM sleep integration of negative memories requires broad associative activation of multi-modal response elements, similar to the AND model. In other words, Environmental Sensitivity characterizes nightmares as activating a primary negative memory trace, then associating and integrating it with numerous response elements; these elements that may be emotional, semantic, or even perceptual/motor. For instance, there is an increase in the frequency and intensity of motor imagery in nightmares (e.g., escaping, defending oneself, fighting, attempting to scream).

Both the AND and Environmental Sensitivity models are analogous to prior nightmare theories in proposing that successful adaptation to stressors through dysphoric dreaming may be a gradual process, i.e., successive iterations of the same emotional memory may need to occur within several different contexts in dreams. However, the intensity of negative emotion in a nightmare may interfere with this function of memory integration in a manner analogous to how negative emotion inhibits associational capacities in wake. That nightmares become pathological when the constituent negative memories are both resistant to extinction and maintain excessive emotional responses is also consistent with predictions of the SFSR model (Walker et al., 2009). Within the dream experience itself, the activation of negative emotional memories, particularly those relevant to prior trauma or abuse, may result in powerful imagery and intense negative arousal; this may create a feedback loop of increasingly negative affect and increasingly repetitive imagery. This pattern of nightmare formation is one that is frequently referenced in Hartmann's contemporary theory of dreaming and nightmares, particularly through his construct of Central Images—nightmare images that become increasingly powerful and persistent with increasing emotion (Hartmann, 1996). This pattern has also been found in waking cognition; that negative emotion decreases associational access and perhaps narrows our focus toward a negative emotion-eliciting event, in essence magnifying it, and resulting in a form of downward spiral of increasing negative affect and diminishing cognitive capacity (Kok & Fredrickson, 2012). Our finding that associational breadth was selectively inhibited for negative emotional words following REM sleep suggests that this downward spiral may influence memory integration during sleep, more specifically, that negative emotion is actively restricting the formation of associations in semantic networks during REM sleep. In this manner,

intense negative emotion in nightmares may interfere with associational processes necessary for the integration of memory.

In sum, an Environmental Sensitivity framework differs least from the AND model in its description of nightmares. Both assume that negative emotion-eliciting events and stressors accumulated during waking life trigger the expression of dysphoric imagery and nightmares. Further, repetitive nightmares most likely reflect failures in REM sleep-dependent emotional memory integration and regulation due to an excessive restriction of associativity induced by a downward spiral of negative affect. In contrast, intensely positive and vivid dreams may reflect increased breadth of spreading activation and memory integration during REM sleep; likewise, positive and bizarre daydreams may reflect enhanced emotional semantic access during wake.

3.4.3.2 Intensified positive and non-nightmare dreams

Perhaps counter-intuitively, the experience of intensely positive dreams, including lucid or archetypal dreams, is correlated with nightmare frequency (Spadafora & Hunt, 1990). Because of this, an Environmental Sensitivity framework, unlike prior models, does not characterize nightmare sufferers only by their nightmares. Instead, it claims that a range of experiences in waking life may be paralleled by both negatively or positively toned, intensified dreaming experiences. While intense negative emotions within nightmares may follow a downward spiral of increasingly negative affect and persistent negative imagery, the complementary position may be true for intense positive emotion, that is, it broadens mindsets, increases associations, and results in vivid and elaborate dreams. In wake, positive emotion leads to broader associational capacity (Corson, 2002; Haänze & Hesse, 1993; Isen, Daubman, & Nowicki, 1987; Isen, Johnson, Mertz, & Robinson, 1985). It also increases openness to others and encourages curiosity and exploration, which can then lead to further increases in positive emotion, in what Kok & Fredrickson (2012) refer to as "upward spiral dynamics". Similarly, in sleep, intense positive emotion in dreams may engender vivid and associative experiences. For example, archetypal, or "Big" dreams tend to describe a euphoric, integrative altered state experience that demonstrates the benefits afforded by positive emotion within a dream. These dreams may relate to even broader integration of positive emotional memory than is normal. Our finding that associational breadth was selectively increased for positive emotional words following REM sleep suggests that positive emotion also facilitates extensive associative

spreading activation through semantic networks during REM sleep. Thus, intense positive dreams may counteract the effects of nightmares to some extent by increasing broad associations in memory.

Nonetheless, both nightmares and positive intensified dreams seem to reflect excessive arousal which is projected in several dimensions (affective, kinesthetic, visuo-spatial). For instance, kinesthetic sensations and concomitant imagery in typical dream reports pertain to more simple sensations of posture, balance, contact and movement. In contrast, intensified dreams display more extraordinary forms of kinesthetic sensation including bodily distortion, vibration, and metamorphosis. In nightmares, these vivid sensations may be associated with inhibition and/or pain, intensified positive dreams may result in feelings of ecstasy. The vividness of these dreams may in some cases stimulate lucid dreams, a type of dream in which the dreamer is aware of and able to control the dream to some extent. Although lucid dreams are rare in the general population, lucid dreaming frequency has been correlated with nightmare frequency, indicating they may be another type of intensified dream enjoyed by nightmare sufferers. It is possible that the intensity of positive emotion, lucidity, and pleasurable body sensations in intensified dreaming may engender more positive or uplifting mood after awakening, in a manner opposite to the post-awakening distress caused by nightmares.

Apart from intensified dreaming, there are signs that nightmare sufferers have a generally enriched dreaming life, including consistently higher than average recall of non-nightmare dreams, and more vivid and affective non-nightmare dreams (Levin, 1994). In typical studies recruiting participants who experience at least 2 nightmares per week, the average participant might still recall 4-5 non-nightmare dreams per week, meaning, the majority of a nightmare sufferers' dreams are, in fact, not nightmares (e.g., Carr et al., 2016). The multiplicity and frequency of dream phenomena experienced by nightmare sufferer suggests that they experience a dreaming life that is at least as positive and vivid as it is distressing and terrifying.

In sum, in contrast to nightmares, vivid dreaming is often an enjoyable experience for nightmare sufferers. The implications of these vivid dreaming experiences are rarely studied in nightmare sufferers, despite being powerful events that may influence both waking life and REM sleep-dependent memory processing as much as do nightmares themselves. In particular, dreams containing intense positive emotions, such as lucid or archetypal dreams, may encourage

broader integration of emotional memory and even lead to downstream effects on mood in a manner analogous to the distress caused by nightmares.

3.4.3.3 Waking imagery

Apart from these variations in dreaming, Environmental Sensitivity may influence waking imagery processes in similar fashion. Individuals who report frequent nightmares are also elevated on measures of fantasy proneness, psychological absorption, and imaginative involvement (Starker, 1974, 1977). For instance, hypnotic susceptibility, vividness of visual imagery and absorption all correlate with nightmare distress but not with nightmare frequency (Belicki, 1992; Belicki & Belicki, 1986); elsewhere fantasy proneness and absorption were associated with nightmare frequency and distress in an additive fashion (Levin & Fireman, 2001, 2002). Arguably, these prior studies focused on the negative and psychopathological correlates of waking imagery in nightmare sufferers. However, our recent finding that individuals with frequent nightmares reported more positive and bizarre daydreams than did control participants challenges this bias, especially since nightmare sufferers reported no differences from controls in the negativity of their daydreams.

The increase in daydream bizarreness among nightmare sufferers may reflect an increased associational capacity, which was likewise shown by our findings that nightmare sufferers have elevated associational breadth. Thus, nightmare sufferers may be characterized by hyper-associativity during both dreaming and waking state daydreams (Carr & Nielsen, 2015; Stickgold et al., 1999). Further, the elevated positivity in nightmare sufferers` daydreams may have facilitated broad spreading activation, similar to effects seen in waking state tasks (Isen et al., 1987; Isen et al., 1985) and thus even further enhancing imagery bizarreness (Garland et al., 2010). Having access to positive and bizarre imaginative content during waking may be an advantageous trait in several contexts, e.g., artistic expression.

Further, our finding that both negative and positive body sensations were significantly elevated in the daydreams of nightmare sufferers may reflect heightened physiological arousal or physiological reactivity in this cohort. While this finding is relatively novel, it suggests that the waking imagery of nightmare sufferers is consistently characterized by more salient or more vivid body sensations, which may contribute to a heightening of emotional experiences. That

both negative and positive body sensations were heightened further supports our claim that nightmare sufferers may be characterized by bi-valent and multi-modal Environmental Sensitivity. Clearly, sensations combining emotion, kinesthesia and other somatic feelings (e.g., pleasure and pain) are particularly relevant imagery attributes to assess in future studies of nightmare sufferers.

In sum, nightmare sufferers' waking daydream imagery, similar to their dreaming imagery, is characterized by a richness across a range of attributes, including affective, sensorial, and bizarre qualities. Their intensified waking imagery thus seems more similar to dreaming in its associative and vivid qualities.

3.4.3.4 Summary

While the AND model focuses on a functional role for dysphoric and nightmare imagery in fear extinction, an Environmental Sensitivity framework suggests that a more complete understanding of nightmare sufferers must also explore their non-nightmare dreams and evaluate how other forms of intensified imagery may be implicated in the functions of REM sleep and dreaming. Accordingly, the Environmental Sensitivity model explores potential functions of intensely positive dreams and even intensified waking imagery. The approach highlights in particular the possibility that intensified positive dreams may facilitate an enhancement of memory processing through a broadening and adaptive integration of positive emotional memories. This positive side of the nightmare-prone personality may even counteract some of the negative consequences (e.g., affect distress) brought about by nightmares themselves.

3.4.4 Conclusions

The Environmental Sensitivity framework diverges from the AND model by highlighting potentially adaptive traits of nightmare sufferers and the presence of positively toned dream and waking imagery in these individuals. In general, Environmental Sensitivity encompasses a body of traits, including the personality trait of boundary thinness, a behavioral propensity for mirror behaviors, and increased semantic associativity along with other traits yet to be tested in the nightmare population, such as sensory-processing sensitivity. These traits

together describe an overarching sensitivity to a range of environmental contexts and an increased depth of processing environmental stimuli. The bi-valent nature of Environmental Sensitivity engenders an intensification of imagery in both negative and positive directions, as seen in both nightmares or intensely positive dreams.

Along the negative dimension of Environmental Sensitivity lies a wealth of research outlining the risks, stressors, and symptoms present in the nightmare sufferer. Nightmares may be associated with maladaptive affective symptoms, including increased prevalence of depression, alexithymia, and anxiety. Intense negative emotion during nightmares may also interfere with REM sleep-dependent processes of progressive emotional memory integration and regulation. These effects may have more serious consequences in the event of exposure to trauma or other adverse events, such as a severe resistance to integration or regulation and the formation of 'flashbulb' memories and replicative PTSD nightmares (see section 3.5). In other words, within the Environmental Sensitivity framework, frequent nightmares nonetheless are considered to be a risk factor for development of other pathologies such as PTSD.

However, the possibility that nightmare-prone individuals may benefit from supportive environments is particularly relevant when considering prognosis and treatment approaches (Hartmann et al., 1991; Levin et al., 1998; Schredl, Kim, Labudek, Schädler, & Göritz, 2013; Schredl, Kleinferchner, & Gell, 1996). While nightmares may become recurrent and pathological and cause significant distress, Environmentally Sensitive individuals may also respond very well to treatment (see section 3.6). Similarly, PTSD patients with a history of nightmares may have a better prognosis than those without, just as individuals with heightened sensitivity may be more responsive to treatment (see section 3.6).

3.5 Frequent nightmares as a risk factor for PTSD

Of all psychiatric and health problems, nightmares are most closely associated with PTSD (Mellman, Bustamante, Fins, Pigeon, & Nolan, 2002; Pillar, Malhotra, & Lavie, 2000; Ross, Ball, Sullivan, & Caroff, 1989). They have been described as a "hallmark symptom" of PTSD (Ross et al., 1989). The prevalence of nightmares after trauma exposure is extremely high, affecting as many as 90% of exposed individuals (Krakow et al., 2002; Neylan et al., 1998; Ross et al., 1989; Woodward, Arsenault, Murray, & Bliwise, 2000) and nightmare frequency in PTSD

can be as high as 6 nights per week (Krakow et al., 2002). These nightmares may continue for the duration of an individual's life; two studies found that frequent, trauma-related nightmares still occur 40–50 years after the trauma (Guerrero & Crocq, 1994; Kaup, Ruskin, & Nyman, 1994).

The occurrence of nightmares prior to trauma exposure predicts the severity of PTSD and other posttraumatic psychiatric symptoms and suggests that nightmares may reflect a risk factor for subsequent psychopathology--PTSD in particular (Mellman, Kulick-Bell, Ashlock, & Nolan, 1995). Our Environmental Sensitivity framework, similar to the AND model, stipulates that the expression of a disposition for nightmares becomes more probable over time as exposure to adverse events accumulates. In the case of idiopathic nightmares, the gradual accumulation of low-grade stressors may lead to the development of nightmares. However, the experience of sudden trauma or severe (continuous) stressors may result in more severe and permanent psychopathology, as in the case of PTSD.

Further evidence that nightmares may represent a risk factor for subsequent development of PTSD comes from epidemiologic and polysomnographic sleep studies. In one large epidemiological survey of Toronto residents, preexistent sleep disturbances, including insomnia (60.9%), excessive daytime sleepiness (71.4%), and parasomnia symptoms including nightmares (40%), were associated with the presence of PTSD (Ohayon & Shapiro, 2000). In a polysomnography study comparing the sleep of PTSD patients and nightmare sufferers, there were almost no differences in sleep macro- and micro-structural measures; the sleep of both groups was punctuated with abnormally high levels of periodic leg movements without and with microarousals—measures correlated with autonomic arousal (Germain & Nielsen, 2003b). Some have reported elevated sympathetic activity for nightmare episodes, e.g., REM sleep-related tachycardia and accelerated respiration, but this also characterizes PTSD nightmares (Fisher et al., 1970; Mellman & Pigeon, 2005). Another study reported that REM sleep eye movement density is atypically high for nightmare sufferers after REM deprivation, but REM density in PTSD patients is also high (Kobayashi, Boarts, & Delahanty, 2007; Nielsen et al., 2010b). Another study found decreased HR variability in the REM sleep of nightmare sufferers, which also occurs in PTSD and is associated with PTSD nightmare frequency (Cohen et al., 2000; Nielsen et al., 2010a).

Physiologically, stress hormones such as cortisol, are elevated in idiopathic nightmare sufferers; similarly, high blood levels of glucocorticoid receptors are a strong predictor of later acquiring PTSD (van Zuiden et al., 2011). In fact, elevated noradrenergic activity, whether central or peripheral, is the most consistent finding in PTSD neuroendocrine studies (Pervanidou, 2008) and serum cortisol is elevated in both PTSD and sub-clinical PTSD patients (Song, Zhou, & Wang, 2008). However, Cortisol Awakening Response (CAR) levels, which are influenced by genetic factors and past adverse experiences (Ouellet-Morin et al., 2009), are abnormally low in both frequent nightmare sufferers and PTSD patients (Chida & Steptoe, 2009).

Thus, there is some evidence that frequent nightmares are related to the psychopathology of PTSD and other psychiatric symptoms. First, nightmares and sleep disturbances prior to trauma exposure predict the development of PTSD; second, physiological factors including higher cortisol and blunted CAR characterize both nightmares and PTSD. For these reasons, we suggest that PTSD and frequent nightmares share a common pathophysiology, and that nightmares may be a risk factor for future development of PTSD**.**

3.5.1 Post-traumatic nightmares as intensified idiopathic nightmares

There is general agreement that some nightmares in PTSD are categorically different from normal dreams and idiopathic nightmares. The AND model describes post-traumatic replicative nightmares as the most severe and pathological form of nightmare, and at this stage, patients may experience a loss of other dream recall. At least 50% of PTSD patients suffer from recurrent replicative nightmares which incorporate clear elements of a traumatic event or may even exactly replicate the traumatic experience (Gehrman, Harb, Cook, Barilla, & Ross, 2014; Leskin, Woodward, Young, & Sheikh, 2002). Of the 20-25% of PTSD patients who experience posttraumatic nightmares that are not an exact replay of a trauma memory, these nightmares are nonetheless often symbolically or indirectly related to the traumatic event (Wilmer, 1996). Elements of reality distortion, changes in time setting, and perceived level of threat can vary and influence the replicative aspect of the trauma memory in posttraumatic nightmares (Esposito, Benitez, Barza, & Mellman, 1999).

Schreuder, Kleijn, and Rooijmans (2000) examined patients 40 years after a traumatic event and found that replicative post traumatic nightmares were related to higher PTSD symptomology compared with patients who suffered from anxiety nightmares that were not necessarily replicative. Another study found that trauma survivors who develop PTSD have more replicative nightmares than trauma survivors who do not develop PTSD (Wittmann, Schredl, & Kramer, 2006). Although there is substantial variation in the extent to which posttraumatic nightmares replicate a trauma, it is possible that symbolic nightmares may be associated with lower levels of symptoms; becoming less recurrent/replicative and more symbolic and thematically similar to idiopathic nightmares as the individual's condition improves (Phelps, Forbes, & Creamer, 2008). Unfortunately, in some cases replicative nightmares exist decades after a trauma and may be perpetually triggered by waking life stressors; these may interfere with any adaptive response and integration of ongoing emotional experience.

Posttraumatic nightmares exhibit more negative, frightening, and threatening content than do idiopathic nightmares. A study of combat veterans found their nightmares to contain replays of actual combat events, high fear for life, and frequent scenes of death and violence, even while they appeared to occur in the subjective present (Esposito et al., 1999). Beyond emotional content, posttraumatic nightmares contain heightened levels of sensory experience, such as olfactory sensations (Harb, Thompson, Ross, & Cook, 2012), which are usually rare in dreams (Zadra, Nielsen, & Donderi, 1998). This can be attributed to the fact that posttraumatic nightmares are globally more intense than typical dreams and nightmares, and are similar to waking flashback memories, which are marked by heightened sensory detail, present tense, fear and helplessness, and increased mentions of death and violence (Hellawell & Brewin, 2004).

Thus, nightmares in PTSD are more intense and pathological than are idiopathic nightmares and are less likely to resolve over time. Their continued maintenance may disrupt emotional integration and engender sustained waking anxiety, hyperarousal, and distress. The amelioration of nightmares can also reduce the severity of other post-traumatic symptoms. In this regard, utilization of evidence-based nightmare treatments should be considered as an adjuvant treatment for PTSD if not as first choice.

3.5.2 Summary

There is evidence that nightmares predict the subsequent appearance of PTSD and other psychiatric symptoms. First, individuals who have in the past experienced distressing trauma (i.e., interpersonal violence) are at greater risk of developing PTSD following a current trauma (Breslau et al., 2004); second, nightmares and sleep disturbances prior to trauma predict PTSD; third, physiological factors, including higher cortisol and blunted cortisol awakening response, characterize both nightmare and PTSD sufferers. Finally, PTSD nightmares seem to be intensified forms of idiopathic nightmares that are more resistant to integration. The treatment of idiopathic nightmares may serve as a preventative measure against PTSD. Further, diagnosis of PTSD with or without prior nightmares may inform treatment approaches and prognosis, since prior nightmares may be evidence of pre-existing Environmental Sensitivity. The amelioration of nightmares can also reduce the severity of other post-traumatic symptoms. Thus, the use of evidence-based nightmare treatments should be considered as an adjuvant or first-choice treatment for PTSD.

3.6 Treatment of nightmares from the Environmental Sensitivity perspective

Recent treatment studies informed by the Environmental Sensitivity approach have been designed to assess the beneficial effects of interventions that not only address the amelioration of negative symptoms but also promote positive functioning (Cassidy, Woodhouse, Sherman, Stupica, & Lejuez, 2011; Eley et al., 2012). For example, one study found that sensory-processing sensitivity predicted treatment response to a depression prevention program; the intervention had a substantial beneficial effect in highly sensitive girls but was not effective for girls who scored low on the measure (Pluess & Boniwell, 2015). Although low and highly sensitive girls did not differ in their initial depression scores at baseline, highly sensitive girls had significantly lower depression scores at 6- and 12-month follow-up assessments. Environmental Sensitivity may predict response to treatment.

PTSD patients with a pre-trauma history of nightmares, who we suggest are more environmentally sensitive, may thus be more receptive to treatment than are PTSD patients who

developed nightmares only after the appearance of PTSD. Accordingly, the Environmental Sensitivity approach might suggest a less aggressive, short-term treatment for sensitive individuals, as PTSD with low sensitivity may require more aggressive or long-term treatment. This claim is supported by several PTSD intervention studies. One study of an 8 week exposure-based cognitive-behavioral therapy for PTSD showed that response to therapy varied as a function of a genetic polymorphism located in the brain-derived neurotrophic factor (BDNF) gene (Felmingham, Dobson-Stone, Schofield, Quirk, & Bryant, 2013). Although there was no difference in PTSD symptoms at pretreatment, patients homozygous for the BDNF Val allele showed a 62% reduction, whereas patients with one or more Met alleles showed only a 40% reduction in PTSD symptoms, suggesting that the BDNF Val/Val genotype increased sensitivity to exposure therapy. In another study, adult survivors of the war in Northern Uganda underwent treatment for PTSD; a genetic polymorphism in the FK506-binding protein, a protein that moderates the glucocorticoid receptors, predicted the response to exposure therapy at 10 months post-treatment (Wilker et al., 2014). While all patients had similar responses at 4 months, the C allele group (vs. T allele) showed more improvement at 10 months, suggesting that improved well-being at 4 months promoted future improvement and sensitivity to support in the C allele group. In both studies, biological markers reflected individual differences in sensitivity to treatment. Thus, treatment of frequent nightmares, as well as PTSD with a history of frequent nightmares, may benefit from focusing on existing and novel approaches to nightmare treatment that target their sensitivity to positive environmental influences and promote general shifts in emotional cognition towards more positive and adaptive cognitions, which would then serve to promote future resilience in the face of adversity (e.g. upward spiral dynamics, see Kok & Fredrickson, 2012).

In practice, an Environmental Sensitivity approach to treatment would entail awareness and utilization of nightmare sufferers' sensitivity to positive contexts and interventions, encouraging more positive attitudes towards dreaming and imagination, and recognizing creativity and emotional sensitivity as potential strengths, rather than weaknesses. The treatment of frequent nightmares may be a clinically significant preventative measure against future development of PTSD, as well as an informative outcome measure for treatment studies of nightmares in PTSD. Treatments targeting nightmares in PTSD with cognitive-behavioral

therapy (Germain & Nielsen, 2003a) are successful in alleviating not only nightmares but also associated PTSD symptoms, anxiety, depression and disturbed sleep. Presence of pre-existing nightmares in PTSD may serve as an indicator of Environmental Sensitivity, which may be useful in determining the aggressiveness, length or type of treatment that should be prescribed.

The following section discusses some existing and emerging approaches relevant to the treatment of both idiopathic and PTSD nightmares from an Environmental Sensitivity perspective. Existing psychotherapeutic options for the treatment of nightmares are both available and efficacious; variants of imagery rehearsal techniques, used either in monotherapy or in conjunction with cognitive behavioral therapy for insomnia, have a strong base of evidence. More recent approaches, such as training in cognitive-affective regulation through techniques of cognitive reappraisal (positive psychology), mindfulness, or contemplative practice may serve as protective factors in the face of future stress and trauma. Also, training in lucid dreaming may even allow the application of such techniques within the dream state itself.

3.6.1 Psychotherapeutic and alternative approaches

3.6.1.1 Image rehearsal therapy

The most common and successful psychotherapeutic treatment for frequent nightmares is Imagery Rehearsal Therapy (IRT; Aurora et al., 2010). This treatment is a modified form of cognitive behavioral therapy that focuses on altering the nightmare as it is mentally rehearsed during the wake state. The first step is to imagine the nightmare and write it down. Then, the nightmare is re-written with a more desirable outcome either through mental imagery or drawing. Finally, the revised story is rehearsed several times prior to sleep. This treatment is based on the assumption that nightmares are a learned behavior, and that activating and practicing a more adaptive version of the nightmare will allow the nightmare script to be modified and reconsolidated during wake and then generalized into sleep. This technique is practiced for 10-20 minutes each day.

IRT practiced in this way reduces nightmares and associated distress (Krakow & Zadra, 2006) and merits a level A recommendation from the American Academy of Sleep Medicine (Aurora et al., 2010). One study, a randomized controlled trial of 168 traumatized women,

demonstrated that IRT is a brief, effective, well-tolerated treatment for chronic nightmares associated with moderate to-severe PTSD symptoms (Krakow et al., 2001); IRT significantly improved disturbing dreams, sleep quality, and PTSD symptoms (60% reduction) and the effects were maintained at 3- and 6-month follow-up. A second study demonstrated a sustained reduction of nightmare frequency at 30 months in 2 groups of 10 patients treated for chronic nightmares with IRT (Krakow, Kellner, Neidhardt, Pathak, & Lambert, 1993). At 3-month follow-up the IRT group had a 72% reduction in nightmare frequency compared to a 42% reduction in a comparison group that only recorded their nightmares in a diary for 1 month. The IRT group also had greater decreases in concurrent negative symptoms, including anxiety, hostility, and distress. In a third study, IRT decreased nightmare frequency in 58 subjects with chronic nightmares; at 18 months, 68% of the remaining 53 subjects no longer met criteria for nightmare disorder (Krakow, Kellner, Pathak, & Lambert, 1996). In sum, IRT is effective in reducing nightmares and related symptoms in patients with either PTSD or idiopathic nightmares.

3.6.1.2 Positive psychology

A positive psychology approach to the treatment of nightmares first acknowledges the variety of positive and enriching dreams that may be experienced by the nightmare sufferer, as opposed to focusing exclusively on the occurrence of nightmares. Simply establishing a more balanced appreciation for the individual's spectrum of dream experiences places the occurrence of nightmares in a larger, more emotionally balanced perspective, with an emphasis on both risk and resilience factors.

As mentioned earlier, while nightmares may be considered a form of intensified dreaming characterized by intense negative arousal and content, there are other forms of intensified dreaming that result in positive, integrated, and even altered state experiences. The notion of "upward spiral dynamics" suggests that positive emotions, such as joy, interest, contentment, and love, can broaden cognition, foster resilience, and increase interpersonal trust (Fredrickson, 2001; Fredrickson & Branigan, 2005; Garland et al., 2010). In a fashion opposite to the deleterious effects of repeated aversive experience, repeated experiences of positive emotions can encourage and enable durable positive effects on stress coping mechanisms (Cohn,

Fredrickson, Brown, Mikels, & Conway, 2009; Fredrickson, Cohn, Coffey, Pek, & Finkel, 2008). In this sense, learning to generate and appreciate positive emotions through dream experiences may counter the deleterious effects of negative cognitive-affective patterns—nightmares in the present case.

The shifting of emotional perceptions and reactions away from entrenched negative patterns can be achieved by learning reappraisal or problem solving strategies. Reappraisal involves the generating of positive interpretations of a stressful situation, thereby reducing the distress associated with the situation (Gross, 1998). Consistent training in such reappraisal strategies may shift an individual's perceptions toward more positive affects and cognitions, which may then be reflected in more positive dream experiences. One study that used a positive psychology program (a school based resilience-promoting intervention) in 11- to 12-year old children found that a genetic polymorphism in the oxytocin receptor gene predicted life satisfaction after the 3-month intervention (Pluess & Belsky, 2015); only children homozygous for the OXTR T-allele showed a significant increase in life satisfaction scores over the course of the intervention. This pattern of upward spiral dynamics was also demonstrated in a previously mentioned study that found adults with higher vagal tone showed greater increases in positive emotions over a 9-week positive psychology intervention, and this change predicted future increases in vagal tone (Kok & Fredrickson, 2010). In sum, environmentally sensitive individuals may benefit particularly from positive psychology treatment approaches, including reappraisal or resilience-promoting strategies.

3.6.1.3 Lucid dreaming

Lucid dreaming is the awareness that one is dreaming while the dream takes place and is often associated with some limited degree of control over the progression of the dream story. It offers another possible means of re-directing dreams away from negative patterns of nightmare progression toward more positive, expansive, and transformative dream experiences. Further, the increased control inherent in lucid dreaming may enable a greater sense of agency and empowerment in the individual (Spadafora & Hunt, 1990).

Although the induction of lucid dreams has proven difficult and there are large individual differences in the capacity to have them, lucid dreaming has proven to be a learnable skill

(LaBerge, 1980; Snyder & Gackenbach, 1988). As such, it has found application in therapeutic settings (Gackenbach & LaBerge, 1988). Reported benefits of lucid dreaming include the reduction of nightmares, increased ego strength, decreased anxiety and obsessive-compulsive symptoms, increased self-confidence, and increased emotional safety and balance (Brylowski, 1990; Tholey, 1988; Zadra & Pihl, 1997). The American Academy of Sleep Medicine promotes lucid dreaming therapy as a viable treatment for nightmares based on two treatment studies (Aurora et al., 2010). The first study demonstrated that at 12-week follow-up, 2 hours of individual lucid dream training was more effective than 2 hours of group lucid dream training, although both showed a significant decrease in nightmare frequency compared to baseline (Spoormaker & Van Den Bout, 2006) and to a control group who showed no change . A second study, a case series of 5 patients with either idiopathic or posttraumatic nightmares, showed alleviation of recurrent nightmares at 1 year when lucid dream training was used in conjunction with relaxation therapy and guided imagery (Zadra & Pihl, 1997).

More recently, one study incorporated lucid dream training into a gestalt therapy treatment of nightmares with some indicators of success (Holzinger, Klösch, & Saletu, 2015). First, lucid dream training served as a motivational factor that improved patient attitudes towards dreaming; dreams were no longer a source of fear. Second, patients with lucid dream training showed a continuous increase in dream recall frequency in parallel with a decrease in nightmare frequency. Thus, approaches oriented towards training in lucid dreaming may lead to increases in positive affect and may allow the intensified dreaming process to change from producing frequent and habitual nightmares to producing more frequent positive and integrative dreams.

3.6.1.4 Contemplative Practice

While positive psychology promotes the therapeutic increase of positive cognitions and decrease of negative emotions, it is possible that any dreams with overly intense emotions, including positive dreams, may be maladaptive. This is, in fact, another possible explanation for the aforementioned finding that nightmare frequency is correlated with lucid and archetypal dream experience (Spadafora & Hunt, 1990), in that all three types of dreams may represent a failure of dream processes to regulate emotion. Such a possibility is supported by anecdotal

reports from practiced lucid dreamers, who indicate that intense positive emotions in a lucid dream can result in an awakening, just as negative emotions do in nightmares (Waggoner, 2008).

The idea that an excess of positive emotion is undesirable in human consciousness more generally is in line with several contemplative schools of thought, which consider any intensified emotion as indicative of underlying habit patterns of attachment and aversion that are perpetual causes of suffering. However, contemplative science suggests another possible distinction relevant to Environmental Sensitivity. On the one hand, hedonistic positive emotions, such as sexual pleasure, may be experientially and functionally distinct from expansive and adaptive positive emotions, such as empathy and compassion, which are beneficial for the self and others. Contemplative practices typically focus on promoting the second type of positivity. In this sense, it is perhaps the second type of selfless positive affect which is exemplified in archetypal or "big" dreams, and is integral to cognitive theories purporting expansive and adaptive functions of positive emotion. Accordingly, contemplative practices may be especially relevant to nightmare treatment.

Within meditation practices, intentional training such as open monitoring, self-transcendence, and compassion-based reflection are associated with neuroplastic changes in the brain (Desbordes & Negi, 2013). For example, recent research on compassion-based meditation training showed alterations in brain networks that are responsible for social cognition and emotion regulation (Condon, Desbordes, Miller, & DeSteno, 2013). Thus, movement-based contemplative practices, such as yoga, may be particularly relevant for treating frequent nightmare sufferers, as these are embodied and attentive to kinesthetic and vestibular sensations, while promoting non-judgemental cognitive affective awareness (Solomonova, 2015). Given that physiological arousal and affective-kinesthetic imagery are particularly heightened in individuals susceptible to nightmares, training in interoceptive awareness may have a positive effect on their wake and dream experiences alike. Both meditation and tai chi have been associated with lucid dreaming and archetypal dream qualities (Faber, Saayman, & Touyz, 1978; Hunt & Ogilvie, 1988). Further, lucid dreamers show superior spatial ability and physical balance (Snyder & Gackenbach, 1988; Spadafora & Hunt, 1990). In this regard, movement-based contemplative practices may promote the expansive and elaborate imagery that is typical of lucid and archetypal dreaming.

In sum, intentional contemplative practices and corresponding changes in underlying neural control of cognitive and affective regulation may carry over to positively influence dreams, and potentially sleep-dependent emotional memory processing, as well.

3.6.2 Summary

In general, the significance of Environmental Sensitivity for the treatment of nightmares is that, in lieu of focusing only on abolishing negative content, treatment can simultaneously focus on promoting and drawing attention to the already present positive sensitivities of nightmare sufferers as a means of decreasing their distress, anxiety, and negative habit patterns. Training focused on modifying emotion regulation strategies, such as positive psychology or contemplative approaches, and increasing dream awareness, such as lucid dreaming, may prove beneficial to decreasing nightmare frequency and distress. Further, given the bidirectional relationship between dream content and symptomology, enrichment of dreaming life may coincide with general improvement in affective and cognitive symptoms (Rosner, Lyddon, & Freeman, 2004).

4. Conclusions

The Associational Breadth task developed for Study 1 proved successful in demonstrating a selective association between REM sleep and a priming effect for emotional cue-words—especially for cue-words of a positive emotional valence. As predicted, when participants were awakened from REM sleep, the semantic atypicality of their word associations increased in response to emotion cue-words that had been primed prior to sleep, relative to cue-words that were either not emotional or not primed. This pattern of differences was not seen for participants awakened from NREM sleep or who had not slept at all.

We speculate that studying a list of cue-words prior to sleep caused them to be 'tagged' for memory consolidation (Redondo & Morris, 2011) and subsequently reactivated during REM sleep, which facilitated a broad spread of activation through semantic memory networks relevant to the primed cue-words. Because REM sleep is particularly sensitive to emotional material (Walker & van Der Helm, 2009), activation of primed emotion words was likely favored over non-emotion words. When participants were awakened from REM, but not NREM sleep, the broad associational links activated for primed emotion words were presumably more easily accessed and led to the unusual associational responses provided in this condition. Our post-hoc finding of a priming effect selective for positive cue-words is consistent with previous work showing that positive mood facilitates spread of activation (Topolinski & Deutsch, 2013), and improves success with RAT solutions (Corson, 2002; Haänze & Hesse, 1993; Isen, Daubman, & Nowicki, 1987).

This selective positive priming effect was replicated in Study 2, where both nightmare and control participants showed REM sleep-dependent changes in Associational Breadth, with associational responses being relatively broadened in response to positive cue-words and restricted in response to negative cue-words. This finding at once replicates our finding from Study 1 of a selective positive priming effect, while expanding this effect to show a differential influence of positive and negative emotional words on associational access after REM sleep priming. Similar findings have been shown for waking state tasks. For example, induction of positive affect leads to the production of more broad semantic associations in the laboratory (Isen et al., 1985); on the other hand, sadness leads to more constrained and specific item

processing (Storbeck & Clore, 2005). These consistent findings not only further validate the notion of affect-mediated semantic network access, but they support our Associational Breadth priming task as a valid measure of this differential effect.

While these principal findings support a role for REM sleep in the integration of recent emotional memory traces, we also found an unexpected negative correlation between priming effect and time and percent of REM sleep. It is possible that consolidation of memory during REM sleep is also modulated by a mechanism of emotional regulation at this time, as described by the SFSR model of emotional memory processing (Walker & van Der Helm, 2009). The SFSR model stipulates that integration of emotional memory traces during REM sleep occurs in tandem with the progressive diminution of the emotional charge of these memory traces. Accordingly, in Study 1, primed emotional words may have been queued for both consolidation and down-regulation during REM sleep. With increasing time in REM sleep, the prime words may have become progressively denuded of their emotional charge, resulting in decreasing priming effects.

These findings were again expanded in Study 2, where REM priming effects were shown to completely dissipate following a one-week delay in the control group. While conceptually replicating a negative association between time in REM sleep and priming effects, this finding further suggests that SFSR processes may occur over multiple nights. We propose that initial REM sleep-dependent changes in associative access dissolved as the emotional cue-words became either fully integrated into memory or fully stripped of their affective charge over time, and one week later the cue-words benefited from strengthened consolidation and faster speed of access (Walker & van Der Helm, 2009). However, nightmare participants did not show this improvement in reaction time, and instead showed an enduring priming effect at one-week re-test. It is possible that the cue-words were either not fully integrated into memory or their affective charge was not down-scaled over the 1-week delay, resulting in sustained priming effects one week later. There are several potential explanations for this. One possibility is that heightened arousal at encoding or during the intervening 7 days, perhaps even within a nightmare, may have interfered with successful down-regulation of emotional memory traces. In any case, these findings imply that nightmare sufferers may experience prolonged arousal

and/or inadequate integration of emotional experiences (Agargun et al., 2003; Csoka, Simor, Szabo, Kopp, & Bódizs, 2011).

Several authors consider dreaming, and perhaps moreso disturbed dreaming and nightmares, to be implicated in REM sleep-dependent functions of emotional memory integration and down-regulation. Although our analyses of imagery reports do not demonstrate a role for dreaming in memory consolidation, they do indicate that such a role may be studied advantageously using morning nap dreams. In particular, dream recall is higher from morning naps and REM and NREM nap dreams are similar in content to dreams sampled from nighttime REM and NREM sleep. For our morning naps protocol, we also developed a daydreaming procedure to allow controlled comparisons of nap dreams with waking state imagery; this procedure ensured that all participants were engaged in similar types of activity during the control interval.

Our sleep/wake imagery comparisons in Study 1 suggest some features of nap dreaming and daydreaming that may or may not be implicated in memory consolidation. Relatively higher ratings of bizarreness in REM nap dreams could be indicative of an increase in the associativity of semantic memory networks during REM sleep. In contrast, the lower bizarreness scores for daydreams could reflect the more structured networks underlying task-focused attention (Smallwood, Obonsawin, & Heim, 2003), while similarly low bizarreness ratings in NREM nap dreams could reflect the operation of similarly structured memory networks. The elevated emotional intensity of REM as compared to NREM dream reports may reflect that fact that REM sleep is particularly important for the consolidation and regulation of emotional memory (Groch, Wilhelm, Diekelmann, & Born, 2013; Nishida, Pearsall, Buckner, & Walker, 2009), whereas NREM sleep is implicated in direct replays of episodic memories. However, emotional intensity ratings for REM nap dreams were of only moderate intensity (3.9 to 5.4 out of 8) and were equivalent to those for daydreams, suggesting a predominance of emotional experience in both waking and REM dreaming. Finally, the relatively vivid sensory experience in REM nap dreams is consistent with findings that REM sleep is associated with the consolidation of visuo-motor and procedural learning tasks (Aubrey, Smith, Tweed, & Nader, 1999; Plihal & Born, 1999), both of which may rely on activation of sensorimotor networks.

Findings from Study 2 suggest that nightmare sufferers have more intensified daydreams and nap dreams than control participants. Specifically, the nightmare group reported heightened positivity, body sensation, and bizarreness ratings in their daydreams, but only heightened body sensation ratings in their nap dreams. These findings agree with prior research showing that nightmare sufferers have generally intensified dreaming, including more vivid and immersive daydream and dream experiences, despite being typically characterized only by their nightmares (Levin & Nielsen, 2007; Spadafora & Hunt, 1990). In fact, our nightmare group did not show higher negativity than control participants in either their nap dreams or daydreams.

The finding that nightmare sufferers had higher bizarreness ratings in their daydreams than did control participants might be considered to reflect heightened semantic associativity in this group. This was supported by our finding that nightmare sufferers have elevated emotional Associational Breadth on both a baseline task and a one-week re-test. We suspect that heightened Associational Breadth scores reflect a broader than usual spread of activation in semantic networks (Carr & Nielsen, 2015b), and that imagery bizarreness in both dreams and daydreams reflects this heightened associational activity (Carr et al., 2016; Carr & Nielsen, 2015b; Stickgold, Scott, Rittenhouse, & Hobson, 1999). That Associational Breadth and daydream bizarreness were elevated in nightmare participants might also be related to the relatively high levels of positivity in their daydreams. To illustrate, access to semantic networks is increased by positive mood in waking state tasks; thus, positivity during daydreams may have facilitated spreading activation in semantic memory networks, enhancing both Associational Breadth and imagery bizarreness (Garland et al., 2010). In general, our findings support prior literature portraying nightmare participants as creative individuals, perhaps benefitting from fluid and broad associational abilities, as well as vivid waking fantasy.

In sum, empirical findings from Study 2 support the notion that nightmare sufferers have altered emotional cognition and intensified imagery. In waking, they display uncommon emotional associations, along with bizarre and vivid daydreams. Following a REM sleep nap, they show changes in associational access similar to that of control participants, along with similar affect and bizarreness ratings in dream imagery. However, one week later, nightmare participants continued to show a robust priming effect whereas the control group did not, suggesting nightmares may interfere with emotional memory integration or down regulation

over time. This deficit that may be related to hyperarousal, partially supported by the presence of vivid affective body sensations within daydream and dream imagery reports of nightmare sufferers. Overall, results portray the nightmare sufferer as an individual who may benefit from broad and creative associational capacity and vivid imagery, while suffering from inadequate emotional memory integration and potential mental health consequences. These results broaden views of nightmare pathology and led to development of a novel Environmental Sensitivity framework of frequent nightmares.

In general, Environmental Sensitivity models claim that individual differences in sensitivity apply to a variety of environmental contexts, including both negative and positive, as well as perceptual and sensory environmental contexts. On the negative dimension, an Environmental Sensitivity framework absorbs existing research showing that nightmare sufferers are characterized by several dysphoric symptoms, which we found in the form of higher distress, alexithymia and depression scores and higher retrospective estimates of recalling bad dreams and nightmares. However, an Environmental Sensitivity framework offers a complementary positive dimension of frequent nightmares. In the case of nightmare sufferers, the presence of adaptive traits such as boundary thinness, heightened motor-affective resonance, and semantic associativity seem to reflect sensitivity to a range of stimuli, including emotional, perceptual/motor, and semantic stimuli. Further, such bi-valent and multi-modal Environmental Sensitivity is evident in the intensified imagery experienced by nightmare sufferers, which is amplified in several dimensions including emotional intensity, amount of body sensations, sensory vividness, and hyper-associative bizarreness. Practically speaking, Environmental Sensitivity may be maladaptive in the face of stressors and associated with inadequate regulation of emotion, although it may be adaptive within supportive contexts and associated with advantageous positive outcomes.

Framing frequent nightmares within an Environmental Sensitivity framework has broad implications for treatment of idiopathic nightmares, as well as treatment of PTSD with pre-existing nightmares. Environmental Sensitivity approaches for the treatment of nightmares emphasize the potential effectiveness of positive and supportive contexts in decreasing levels of affect distress and emotional dysregulation. We propose several potential avenues of treatment, including positive psychology approaches aimed at training cognitive re-appraisals and shifting

from negative to positive patterns of emotional cognition. Lucid dream training may similarly promote enriched dream experiences while decreasing nightmare frequency and associated distress. These approaches may likewise be applied in the treatment of PTSD with pre-existing nightmares, since these individuals would presumably be highly sensitive and thus more responsive to treatment.

Overall, the dissertation supports claims that REM sleep is hyper-associative, established both through evidence that REM sleep led to more broad associational responses on a semantic task, and that ratings of REM dream reports were consistently more bizarre than both NREM and waking daydream reports. Results from Study 1 support a specific role for REM sleep in associative integration of positive emotional stimuli, conceptually replicating work from waking studies showing positive emotion to have a facilitating effect on spreading activation in semantic networks. These findings were confirmed in Study 2 where we not only replicated a facilitative effect of positive stimuli on broad associational activation, but also found a restricting effect of negative stimuli on semantic spread. These findings enlighten how intense negative or positive emotional experiences influence REM sleep-dependent emotional memory integration. For instance, adverse events and trauma may lead to severely restricted 'flashbulb' memories that are resistant to integration, mirrored in nightmares containing powerful and repetitive central images. On the other hand, positive stimuli facilitate spreading activation and may be reflected in expansive and adaptive 'big' dreams. An unexpected negative correlation between priming and time in REM sleep (Study 1), along with a complete dissipation of the priming effect in control participants at one-week re-test (Study 2) seem to reflect an underlying emotion regulation function of REM sleep, such as that predicted by the SFSR model of Walker (2009). A persistent priming effect in nightmare participants at one-week re-test suggests that nightmares may interfere with the down-regulation of emotional memory traces. Notwithstanding such deficits, nightmare participants also showed evidence of elevated associational capacity in wake, which was paralleled by bizarre, positive daydream imagery. Our novel Environmental Sensitivity framework takes into account both the deficits and potential benefits conferred by frequent nightmares.

Globally, we suggest that the future study of REM sleep-dependent emotional memory integration may benefit from concurrent study of populations experiencing intensified imagery,

such as nightmare sufferers, since these imagery experiences may reflect changes in breadth of emotional semantic access occurring during REM sleep. Likewise, the future study of nightmare sufferers would benefit from assessment of both negative and positive traits and imagery experiences in order to develop a more complete picture of Environmental Sensitivity in these individuals.

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